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TIDAL PARAMETERS DERIVED FROM THE PERTURBATIONS IN THE ORBITAL INCLINATIONS OF THE BE-C, GEOS-I, AND GEOS-II SATELLITES

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ABSTRACT

The tidal perturbations in the orbital inclinations of the BE-C, GEOS-I, and GEOS-II satellites are analyzed. Effective tidal Love numbers and phase angles for the O_1, K_1, M_2, K_2, P_1, and S_2 tides are recovered. The effective tidal phase angles tend to be on the order of a few degrees. The effective tidal Love numbers are generally less than the solid earth Love number k_2 of about 0.30. This supports the contention of Lambeck, et al. (1974) that the ocean tides give an apparent depression of the solid earth Love number. Ocean tide amplitudes and phases are calculated for the above tides assuming $k_2 = 0.30$ and the solid earth lag angle $\phi_2 = 0$. The results show good agreement with Felsentreger, et al. (1976) on GEOS-I but not on GEOS-II. The M_2 effective Love number and phase angle are poorly determined, but give a lunar acceleration of -29 ± 15 arc sec/(100 yr)^2, an energy dissipation of $-3.6 \pm 1.8 \times 10^{19}$ erg/sec, and a tidal function time scale of 1.4×10^9 yr when averaged over all three satellites. This is in fair agreement with current estimates.

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TIDAL PARAMETERS DERIVED FROM THE PERTURBATIONS IN THE ORBITAL INCLINATIONS OF THE BE-C, GEOS-I, AND GEOS-II SATELLITES

INTRODUCTION

The sun and moon raise tides on the earth; the displaced mass perturbs the orbits of earth satellites. These perturbations may be analyzed in order to learn about the earth's tides.

Early analyses of the tidal perturbations performed by Kozai (1965, 1968), Newton (1965, 1968), Anderle (1971), Smith, et al. (1973), and Douglas, et al. (1974) were aimed at recovering the Love number k_2 and lag angle ϕ_2 of the solid earth tide. The resulting Love numbers were found to be generally smaller than the well-known value for k_2 of about 0.29 to 0.31 obtained from seismic studies (e.g., Longman, 1966). The discrepancy has been ascribed by Lambeck (1974) and Lambeck et al. (1974) to the corruption of the solid earth tidal signal by the ocean tides (and to a lesser extent the atmospheric tides), which Kaula (1962) showed might be significant. The ocean tides give the appearance of Love numbers and lag angles which vary from constituent to constituent. Accordingly, some satellite data have been re-analyzed (Lambeck, et al. 1974; Felsentreger, et al. 1976) in an effort to learn about the solid earth, ocean, and atmospheric tides.

We continue with such a re-analysis here by examining the tidal perturbations in the orbital inclination of three different earth satellites: BE-C (Beacon Explorer C), GEOS-I, and GEOS-II. Table 1 gives pertinent information about the satellites. Inclination perturbations are analyzed because they give a relatively clean separation of tidal effects from other disturbing forces.

THE DATA

The BE-C data consists of 36 laser observations, spanning a 501 day period beginning in July 1970. The amplitude of the variation in inclination is about 1.0 arc seconds (40 meters). For further details, see Smith, et al. (1973). The GEOS-I consists of 142 TRANET Doppler observations spaced over 626 days, beginning in February 1966. The amplitude of the tidal signal is about 1.2 arc second (36 meters). The GEOS-II data is composed of 113 precision reduced camera and TRANET Doppler observations taken over a 651 day period beginning in March 1968. For further details, see Felsentreger, et al. (1976).

In each case the well-known disturbing forces were modelled and removed, so that the remaining perturbations are presumably due almost entirely to the tides.

ANALYTICAL EXPRESSION FOR THE INCLINATION VARIATION

We now derive an analytical expression for the total tidal perturbation in the inclination of the orbit of an earth satellite by modifying the equation for the solid earth tidal potential.

The solid earth tidal potential expressed in orbital elements is given by (Kaula, 1964)

$$U_{\ell mpq} = k_\ell R_E^{2\ell+1} B^*_{\ell m} C_{\ell mpq} \sum_{h,j} C_{\ell mhj} \cdot \cos\left\{ v^*_{\ell mpq} - v_{\ell mhj} - m\theta^* + m\theta + \epsilon_{\ell mpq} \right\} \tag{1}$$

where $B^*_{\ell m} = Gm^* \frac{(\ell - m)!}{(\ell + m)!}$, $C^*_{\ell mpq} = \frac{F_{\ell mp}(I^*)G_{\ell pq}(e^*)}{a^{*\ell+1}}$

and $v^*_{\ell mpq} = (\ell - 2p)\omega^* + (\ell - 2p + q)M^* + m\Omega^*$

The starred (*) quantities refer to the disturbing body (sun or moon) and the unstarred refer to the satellite. The sign in front of the tidal phase angle $\epsilon_{\ell mpq}$ had been minus in Kaula's original formulation; Lambeck, et al. (1974) changed the sign to plus, which makes the important phase angles positive quantities in the case of a frictionally-delayed solid earth tidal bulge. We follow the convention of Lambeck, et al. here.

We wish to find the total tidal potential $T_{\ell mpq}$ caused by the solid earth, oceans, and atmosphere, since this is the potential felt by a satellite. We limit the discussion to $\ell = 2$, since the second degree terms dominate the motion of

the satellite and the evolution of the earth-moon system. (For a discussion of fourth degree terms, see below and Appendix 2.)

In finding the total tidal potential of degree 2 we make the following assumption: the amplitude of the potential and the phase angle become frequency-dependent. This means that the solid earth Love number k_2 in eq. (1) is replaced by the effective Love number d_{2mpq} and the solid earth phase angle ϵ_{2mpq} is replaced by the effective phase angle δ_{2mpq}. The adjective "effective" is necessary since we now refer to the tidal response of the entire earth, and not just the solid earth. This procedure takes care of any possible frequency dependence of the solid earth Love number, the response of the oceans, and the atmosphere tides. The letters "d" and "δ" are chosen to avoid possible confusion with the solid earth tides.

The total tidal potential is now to be substituted in Lagrange's planetary equations to find the perturbation in the inclination of the orbit of an earth satellite. Before doing this, however, let us make several simplifications: (a) omit the zero sum $-m\,\theta^* + m\,\theta$, (b) consider only terms for which $j = 0$ and $\ell = 2h$, to be rid of dependence on the satellite eccentricity and mean anomaly, and (c) consider only terms for which $q = 0$ to be rid of small terms which depend on the eccentricity of the disturbing body. The total tidal potential now becomes

$$T_{2mp0} = d_{2mp0} \frac{Gm^*}{R_E} \frac{(2-m)!}{(2+m)!} (2 - \delta_{0m}) \left(\frac{R_E}{a^*}\right)^3 \left(\frac{R_E}{a}\right)^3$$

$$\cdot\, F_{2mp}(I^*)\, F_{2m1}(I) \cos\left\{(2-2p)(M^* + \omega^*) + m\Omega^* - m\Omega + \delta_{2mp0}\right\} .$$

Substitution of this potential into the Lagrange equation

$$[\dot{I}]_{\ell mpq} = -\frac{1}{\sqrt{GM_E a}\;(1-e^2)^{1/2}\;\sin I}\;\frac{\partial T_{\ell mpq}}{\partial \Omega}$$

and integration with respect to time yields

$$\Delta I_{2mp0} = \frac{d_{2mp0}}{\sqrt{GM_E a}\;(1-e^2)^{1/2}\;\sin I}\left[(2-\delta_{0m})\frac{(2-m)!}{(2+m)!}\;m\right]\left(\frac{R_E}{a^*}\right)^3\left(\frac{R_E}{a}\right)^3$$

$$\cdot\; F_{2mp}(I^*)\,F_{2m1}(I)\;\frac{\cos\left\{(2-2p)(\omega^*+M^*)+m\Omega^*-m\Omega+\delta_{2mp0}\right\}}{[(2-2p)(\dot{\omega}^*+\dot{M}^*)+m\dot{\Omega}^*-m\dot{\Omega}]} \qquad (2)$$

We have assumed in the integration that the satellite elements, a, e, and I, as well as the nodal rate $\dot{\Omega}$ are constants. We have also assumed that $\dot{\omega}^*+\dot{M}^*$, $\dot{\Omega}^*$, and I^* remain constant. This last set of assumptions must be removed in the case of the moon when considering periods of time longer than a few years, due principally to the motion of the lunar node on the ecliptic.

The tidal inclination perturbation is thus given by

$$\Delta I = \sum_{\substack{m,p\\ \text{Moon}}} \Delta I_{2mp0} + \sum_{\substack{m,p\\ \text{Sun}}} \Delta I_{2mp0} + \Delta I_0$$

where ΔI_0 is a constant of integration.

We note in passing several features of eq. (1). First, tides for which m = 0 do not perturb the orbital inclination; thus we obtain no information on these tides. Second, the periods of the tides felt by the satellite are greatly lengthened

over their periods on the earth's surface, due to the replacement of $\dot{\theta}$ in the frequency by $\dot{\Omega}$. Third, there is no way to separate the K_1^M tide from the K_1^S tide (ℓ_{mpq} = 2110), or the K^M tide from the K_2^S tide (ℓ_{mpq}=2210), since in either case the periods are the same. A hypothesis is needed to do this.

ANALYSIS OF THE DATA

Eq. (2) may be conveniently written

$$\Delta I_{2mp0} = c_{2mp0} [\quad] \cos \left\{(2-2p)(\omega^* + M^*) + m\Omega^* - m\Omega\right\}$$

$$- s_{2mp0} [\quad] \sin \left\{(2-2p)(\omega^* + M^*) + m\Omega^* - m\Omega\right\}$$

for the analysis of the data. Here $c_{2mp0} = d_{2mp0} \cos \delta_{2mp0}$, $s_{2mp0} = d_{2mp0} \sin \delta_{2mp0}$, and the empty brackets denote a factor common to both terms. The coefficients c_{2mp0} and s_{2mp0} are found from multiple linear regression, from which the effective Love numbers and phase angles may be easily computed.

The regression analyses for the three satellites were carried out with the computer program described in Appendix 3. In each case the tides with the largest expected amplitudes in eq. (2) were retained in the analysis and the smaller ones ignored. The theoretical amplitudes in the solid earth signal were conveniently used to pick out the major contributors.

Table 2 gives the regression solutions. The effective Love numbers and phase angles for the K_1^M, and K_1^S tides are assumed to be the same; likewise for the K_2^M and K_2^S tides. The resulting inclination curves and residuals are shown in Figures 1 - 6.

Another computer run was made in which the effective phase angles of all but the K_1 tide in the BE-C data and the K_1 and S_2 tides in the GEOS-I and GEOS-II data (the major contributors in each signal) were set to zero. No major changes in the effective Love numbers (or in those effective phase angles solved for) took place. A similar computer run was made with only the first 28 points in the BE-C data and the first 72 points of the GEOS-I data retained. Also, 20 neighboring points in the GEOS-II data taken from the middle of July to the end of September in 1968 were removed and a run made. Again no major changes in the effective Love numbers and phase angles took place, indicating the stability of the solutions. However, the deleted points in the GEOS-II data were chosen not to disturb the basic signal, due to the spacing of the data.

Examination of Table 2 reveals good agreement between the BE-C and GEOS-I results, but poor agreement between GEOS-II and the other two satellites. Also, there is good agreement between our determination of ocean tide parameters and that of Felsentreger, et al. (1976) for GEOS-I, but no agreement on the ocean tide parameters for GEOS-II (see below). The cause of this discrepancy is unknown; hence the GEOS-II results must be treated with caution.

Most of the effective Love numbers given in Table 2 are smaller than the solid earth Love number k_2 of 0.29 to 0.31. This is in general accord with the ocean tide models and charts given in Table 2 of Lambeck, et al. (1974). The only entry in that table which predicts an effective Love number greater than k_2 is the O_1 tide chart of Dietrich. (The S_2 tide model of Bogdanov and Magarik

predicts an apparent increase in the effective Love number for GEOS-II due to a fourth degree term.) The phase angles are on the order of a few degrees, as expected, although some are negative and the BE-C K_2 and the GEOS-II P_1 effective phase angles are embarrassingly large. Also, the BE-C K_2 and GEOS-II S_2 effective Love numbers are rather large and the GEOS-II P_1 effective Love number is rather small. These presumably reflect the inadequacies of the data. However, it will be noted that all three satellites indicate a remarkably small effective Love number for the P_1 tide, apparently indicating a large ocean tide effect. If this effect is real it is highly interesting, since the O_1 tide (the lunar counterpart of the P_1 tide) shows no similar behavior. In fact, the O_1 effective Love number should be larger than k_2 according to Dietrich's chart, as mentioned above. Unfortunately, we have only one poorly determined effective Love number for the O_1 tide, and no mathematical models for either the O_1 or P_1 tide appear to exist.

SEPARATION OF OCEAN AND EARTH TIDES

We now solve for the ocean tide parameters from the satellite data in the manner of Felsentreger, et al. (1976). To do so, we assume that the tidal signal consists solely of the solid earth and ocean tides; this lumps the small atmospheric tides (principally an S_2 tide) with the ocean tides.

Separation of the ocean from the solid earth tides requires knowledge of the solid earth tidal response. If we assume the solid earth Love number to be

frequency-independent, then from Appendix 2 we have

$$c_{2mp0} = d_{2mp0} \cos \delta_{2mp0} = k_2 \cos \epsilon_{2mp0} + Z_{mp}(1 + k_2') \begin{bmatrix} C^+_{(2mp0)2m} & \sin \epsilon^+_{2m} \\ C^+_{(2mp0)2m} & \cos \epsilon^+_{2m} \end{bmatrix} \begin{matrix} \text{m even} \\ \text{m odd} \end{matrix} \tag{3}$$

$$s_{2mp0} = d_{2mp0} \sin \delta_{2mp0} = k_2 \sin \epsilon_{2mp0} + Z_{mp}(1 + k_2') \begin{bmatrix} C^+_{(2mp0)2m} & \cos \epsilon^+_{2m} \\ -C_{(2mp0)2m} & \sin \epsilon^+_{2m} \end{bmatrix} \begin{matrix} \text{m even} \\ \text{m odd} \end{matrix} \tag{4}$$

where $\epsilon_{2mp0} \approx m\phi_2$ (Lambeck, et al. 1974), ϕ_2 being the solid earth lag angle and k_2' the second degree load deformation coefficient.

The question arises as to what values to choose for k_2, k_2', and ϕ_2. Let us pick $k_2 = 0.30$ and $K_2' = -0.30$, in accord with Longman (1966), and $\phi_2 = 0$, in accord with a high Q (~ 230) for the earth's mantle (see, e.g. Stacey, 1969).

The two rightmost columns of Table 2 give the resulting ocean tide amplitudes and phases. These are to be compared with Table 2 of Lambeck, et al. (1974) and Table 1 of Felsentreger, et al. (1976).

The ocean tide amplitudes in our Table 2 have absorbed the fourth (and higher) degree terms in the ocean tidal potential, which Lambeck, et al. (1974) showed

to be important for some tides. The fourth degree terms could be solved for from observations of two or more satellites, since these terms cause an apparent variation in the second degree effective Love number from satellite to satellite (see Appendix 2). We have chosen not to solve for them here, since the differences between the effective Love numbers tend to be several times larger than those predicted by the ocean tide models and charts; and there are no clear trends.

We may also make a rough estimate of k_2 from the ocean tides charts and models, in the manner of Lambeck, et al. (1974). For this we set

$$d_2 \approx k_2 + Z_{mp}(1 + k_2') \begin{bmatrix} C^{+}_{(2mp0)2m} & \sin \epsilon^{+}_{2m} \\ C^{+}_{(2mp0)2m} & \cos \epsilon^{+}_{2m} \end{bmatrix} \begin{matrix} m \text{ even} \\ \\ m \text{ odd} \end{matrix}$$

and substitute the ocean tide amplitudes and phases in Table 2 of Lambeck, et al. (1974) into the right side of this equation and our values into the left. A simple average of all charts, models and satellites yields $k_2 \approx 0.27$. Performing the same calculation without the GEOS-II results gives $k_2 \approx 0.26$.

The effective Love numbers and phase angles of the well-determined tides permit an estimate of ϕ_2 as well as k_2. Using the K_1 tide from BE-C and the K_1 and S_2 tides from GEOS-I and GEOS-II, in connection with the K_1 and S_2

tides from Table 2 of Lambeck, et al. (1974), we find from eqs. (3) and (4) that $K_2 \approx 0.29$ and $\phi_2 \approx 1.5°$. Once again an arithmetic average has been taken.

From ϕ_2 we determine a rough estimate of Q for the mantle, since (see, e.g., Stacey, 1969)

$$Q \approx \frac{1}{\tan \epsilon_{2200}} \approx \frac{1}{\tan 2\phi_2}$$

yielding a value of 19. Omitting the GEOS-II results yields $k_2 \approx 0.28$, $\phi_2 \approx 4.2°$, and $Q \approx 7$.

Only a simple arithmetic average is taken in the computations above because we have treated the ocean tide models and charts as "observations" without knowing how to weight them. Further, the quality of the satellite data prevents us from reading too much significance into the numbers (such as the extremely low Q values). Hence the values computed above indicate only the plausibility of the hypothesis that the ocean tides are responsible for the variations in the effective Love numbers and phase angles.

TIDAL FRICTION

The evolution of the earth-moon system is dominated by the second degree terms in the total tidal potential. In fact the secular rates of change of n_M, a_M, e_M, J, I_s, $\dot{\theta}$, and E may all be written

$$\dot{X} \approx \sum_{mpq} [\dot{X}]_{2mpq}$$

where X is one of the above-mentioned quantities and the right side of the equation has the form (Appendix 1)

$$[\dot{X}]_{2mpq} = P_{2mpq}\, s_{2mpq}$$

The values of P_{2mp0} are given in Table 5. Note that the s_{2mpq} are determined directly from the data by the regression analysis, apart from possible corruption by the fourth degree ocean tide terms.

The $[\dot{X}]_{2mpq}$ may be conveniently arranged in a table, with the entries to be filled in as reliable data become available. Our own tentative values are found in Table 3. These were computed from the weighted average over all three satellites of each s_{2mp0}. Table 4 is similar to Table 3, except that the GEOS-II data have been omitted.

Our value of $\dot{n}_M \approx -29 \pm 15$ arc sec/(100 yr)^2, taken from Table 3, compares favorably with Lambeck's (1975) -34 ± 5 arc sec/(100 yr)^2, computed from ocean tide models and charts. It also agrees well with the astronomically determined values, which range from -37.5 ± 5 to -52 ± 4 arc sec/(100 yr)^2 (Lambeck, 1975). The value of $\dot{n}_M \approx -17 \pm 20$ arc sec/(100 yr)^2 from Table 4 is barely half the current estimates.

Our value of $\dot{E} \approx -3.6 \pm 1.8 \times 10^{19}$ erg/sec from Table 3 is also in good agreement with current estimates. It is bracketed by Miller's (1966) value of -1.7×10^{19} ergs/sec, determined from energy dissipation in shallow seas, and Lambeck's

(1975) value of -5.7×10^{19} ergs/sec, determined from ocean tide charts and models. The number quoted in Table 4 is close to Miller's value, which probably represents a lower limit on the energy dissipation.

On the whole, it would appear that Table 3 agrees better with modern estimates than Table 4. However, Table 3 indicates that the effective phase angle of the S_2 tide is negative, which would speed up the earth's rotation. This is reminiscent of Holmberg's (1952) hypothesis that the atmospheric tidal torque, which tends to speed up the earth, balances the frictional torque, which tends to slow the earth down, thus keeping the earth at a steady rotation rate. The data given in Table 3 of Lambeck (1975) does not indicate a negative effective phase angle for the S_2 tide, however.

Our data on the M_2 tide may be used to estimate the time scale of the tidal evolution of the earth-moon system. Taking (see Appendix 1)

$$\dot{a}_M \approx \dot{a}_{2200} \cong \frac{\sqrt{G(M_E + m_M)}}{3M_E a_M^{11/2}} \, m_M R_E^5 \, [F_{220}(I_M)]^2 \, d_{2200} \sin \delta_{2200},$$

multiplying each side by $a^{11/2}$ and integrating with respect to time yields

$$a^{13/2} - a_0^{13/2} = 13/6\sqrt{G(M_E + m_M)} \, \frac{m_M}{M_E} R_E^5 \, [F_{220}(I_M)]^2 \, d_{2200} \sin \delta_{2200}(t - t_0)$$

assuming the inclination, Love number, and phase angle remain constant. At the early time t_0 when the moon was close to the earth $a_0 \approx 0$. Hence the tidal friction age of the earth-moon system is approximately

$$T \approx 6/13 \frac{M_E a_M^{13/2}}{\sqrt{G(M_E + m_M)}\; m_M\, [F_{220}(I_M)]^2\, d_{2200} \sin \delta_{2200}}$$

$$\approx \frac{0.0469}{d_{2200} \sin \delta_{2200}} \times 10^9 \text{ yr.}$$

The above equation gives $T = 1.4 \times 10^9$ yr using the weighted average s_{2200} value for all the satellites, and $T = 2.4 \times 10^9$ yr using the BE-C and GEOS-I data only. These times are obviously much shorter than the age of 4.6×10^9 yr for the earth and moon determined by radioactive dating. A way out of this time scale difficulty has been pointed out by Lambeck (1975). He notes that the tidal torques may have been much smaller in the distant past when the oceans did not flood the continental shelves, and that the ocean basin configuration was much different than it is now, due to continental drift.

DISCUSSION

One might wonder whether the variation in the effective Love numbers is in fact due to the ocean tides and not due to frequency-dependence of the solid earth Love number. Alterman, et al. (1959) show that k_2 does vary with frequency. However, the predicted change in Love number over the tidal frequencies is much smaller than that observed here.

Another possibility is core-mantle resonance. The theories of Jeffreys and Vincente (1957) and Molodensky (1961) both predict a variation in Love number

near the diurnal frequency on the same order of magnitude as that observed here. These theories would not explain the observed differences at frequencies away from the diurnal frequency; but core-mantle resonance cannot be ruled out as a possible contributor to the Love number variation.

Our results lend support to the ocean tide hypothesis of Lambeck, et al. (1974), and indicate what can be done when more data become available. They also indicate directions for further study. Regularly spaced and densely packed laser observations, for instance, would give good information on the short-period M_2 tide. Observations of a low-inclination satellite would also increase the amplitude of the M_2 signal, thus determining it more reliably. If the effective Love number of the P_1 tide is really as small as our data suggests, then a mathematical model of the P_1 ocean tide would be of great interest.

NOTATION

$a^*I^*e^*M^*\Omega^*\omega^*$	orbital elements of disturbing body (sun or moon)
$aIeM\Omega\omega$	orbital elements of satellite
C	moment of intertia of the earth
$C^{\pm}_{nst}$	ocean amplitude

$d_{\ell mpq}$	effective tidal Love number
G	universal constant of gravitation
k_2	solid earth Love number, degree 2
k'_s	load deformation coefficient, degree s
m^*	mass of disturbing body (sun or moon)
M_E	mass of the earth
$2\pi nfT$	tidal argument
R_E	radius of the earth
$\delta_{\ell mpq}$	effective tidal phase angle
$\epsilon_{\ell mpq}$	solid earth tidal phase angle
$\epsilon^{\pm}_{st}$	ocean tide phase angle

$\dot{\theta}$ rotational speed of the earth

$\bar{\rho}_E$ average density of the earth

ρ_w density of sea water

ϕ_2 solid earth tidal lag angle

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APPENDIX 1

We discuss here the rates of charge of the lunar orbital elements and the orientation and spin of the earth under the influence of tidal friction, and the dissipation of tidal energy.

We treat the earth-moon-sun system as two separate systems, namely earth-moon and earth-sun. Strictly speaking, this is impermissable, since we are dealing with a three body problem. However, the errors made in doing this are small compared to the uncertainties in determining the effective tidal Love numbers and phase angles.

In the following equations we follow the formalism of Kaula (1964), using the sign convention of Lambeck, et al. (1974) and the corrections for the two body problem of Rubincam (1975, Appendix 1).

The secular rate of change in time of the lunar semimajor axis is given by (Kaula, 1964)

$$\dot{a} = \sum_{\ell,m,p,q} [\dot{a}]_{\ell mpq}$$

where

$$[\dot{a}]_{\ell mpq} = 2\sqrt{G(M_E + m_M)}\, \frac{m_M}{M_E}\, \frac{R_E^{2\ell+1}}{a_M^{2\ell+3/2}}\, \frac{(\ell-m)!}{(\ell+m)!}\, (2-\delta_{0m})(\ell-2p+q)$$

$$\cdot\, [G_{\ell pq}(e_M)F_{\ell mp}(i_M)]^2\, d_{\ell mpq} \sin \delta_{\ell mpq}.$$

The moon's mean motion n_M is related to a_M by

$$n_M = \frac{\sqrt{G(M_E + m_M)}}{a_M^{3/2}}$$

so that

$$\frac{dn_M}{dt} = -3/2 \sqrt{G(M_E + m_M)}\ a_M^{-5/2}\ \frac{da_M}{dt}$$

Thus

$$[n_M]_{\ell mpq} = -3\ \frac{G(M_E + m_M)}{a_M^3}\ \frac{m_M}{M_E} \left(\frac{R_E}{a_M}\right)^{2\ell+1} \frac{(\ell - m)!}{(\ell + m)!}\ (2 - \delta_{0m})$$

$$\cdot\ (\ell - 2p + q)\ [G_{\ell pq}(e_M) F_{\ell mp}(I_M)]^2\ d_{\ell mpq}\ \sin \delta_{\ell mpq}.$$

The components of the rate of change of the lunar orbital eccentricity are given by (Kaula, 1964)

$$[\dot{e}_M]_{\ell mpq} = \sqrt{G(M_E + m_M)}\ \frac{m_M}{M_E}\ \frac{R_E^{2\ell+1}}{a_M^{2\ell+3/2}}\ \frac{(1 - e_M^2)^{1/2}}{e_M}\ \frac{(\ell - m)!}{(\ell + m)!}\ (2 - \delta_{0m})$$

$$\cdot\ [(1 - e_M^2)^{1/2}\ (\ell - 2p + q) - (\ell - 2p)]\ \ [G_{\ell pq}(e_M) F_{\ell mp}(I_M)]^2\ d_{\ell mpq}\ \sin \delta_{\ell mpq}.$$

Let us call the angle between the plane of the lunar orbit and the ecliptic J. Then we have approximately (Rubincam, 1975, Appendix 1)

$$[\dot{J}]_{\ell mpq} = \sqrt{G(M_E + m_M)}\ \frac{m_M}{M_E}\ \frac{R_E^{2\ell+1}}{a_M^{2\ell+5/2}}\ \frac{(\ell - m)!}{(\ell + m)!}\ (2 - \delta_{0m})$$

$$\cdot \frac{(\ell - 2p)\cos I_M - m}{(1 - e_M^2)^{1/2} \sin I_M}\ [G_{\ell pq}(e_M)F_{\ell mp}(I_M)]^2\ d_{\ell mpq} \sin \delta_{\ell mpq}.$$

We now turn our attention to the earth. Note that both lunar and solar tidal friction disturb the earth. This is in contrast to the treatment above, where only lunar tidal friction disturbs the moon's orbit. The tidal bulge raised by the moon is geared to the lunar motion, but the solar tidal bulge is not.

From considerations of the conservation of angular momentum the rate of change of the earth's equatorial tilt to the ecliptic is given by (Rubincam, 1975, Appendix 1)

$$[\dot{i}_S]_{\ell mpq} = \frac{Gm^{*2}}{R_E C\dot{\theta}} \left(\frac{R_E}{a^*}\right)^{2\ell+2} \frac{(\ell - m)!}{(\ell + m)!}\ (2 - \delta_{0m})\ \left[\frac{(\ell - 2p) - m\cos I^*}{\sin I^*}\right]$$

$$\cdot\ [G_{\ell pq}(e^*)F_{\ell mp}(I^*)]^2\ d_{\ell mpq} \sin \delta_{\ell mpq}$$

and the slowdown in the earth's rotation by

$$[\bar{\dot{\theta}}]_{\ell mpq} = -\frac{Gm^{*2}}{R_E C}\left(\frac{R_E}{a^*}\right)^{2\ell+2}\frac{(\ell-m)!}{(\ell+m)!}(2-\delta_{0m})\, m$$

$$\cdot\, [G_{\ell pq}(e^*)F_{\ell mp}(I^*)]^2\, d_{\ell mpq}\sin\delta_{\ell mpq}.$$

Let us now derive the rate of dissipation of tidal energy in the earth. The orbital energy in the center of mass frame is

$$E_0 = -\frac{GM_E m^*}{2a^*}$$

and the rotational energy of the earth is

$$E_r = \tfrac{1}{2}C\dot{\theta}^2$$

Therefore the total mechanical energy is simply

$$E = E_0 + E_r = -\frac{GM_E m^*}{2a^*} + \tfrac{1}{2}C\dot{\theta}^2.$$

Thus the rate of dissipation of energy is

$$\dot{E} = \frac{GM_E m^*}{2a^*}\frac{da^*}{dt} + C\dot{\theta}\frac{d\dot{\theta}}{dt}.$$

From the previous equations we derive the relatively compact expression

$$[\dot{E}]_{\ell mpq} = \frac{Gm^{*2}}{R_E}\left(\frac{R_E}{a^*}\right)^{2\ell+2}\frac{(\ell-m)!}{(\ell+m)!}\,(2-\delta_{0m})$$

$$\cdot\,[(\ell-2p+q)n^* - m\dot{\theta}]\,[G_{\ell pq}(e^*)F_{\ell mp}(I^*)]^2\, d_{\ell mpq}\sin\delta_{\ell mpq}$$

It will be noted that the above equations all have the form

$$[\dot{X}]_{\ell mpq} = P_{\ell mpq}s_{\ell mpq}$$

where X is the quantity of interest, $s_{\ell mpq} = d_{\ell mpq}\sin\delta_{\ell mpq}$, and $P_{\ell mpq}$ is a multiplicative factor whose value is easily computed. Table 5 gives the $P_{\ell mpq}$ for $\ell = 2$ (the degree which dominates the evolution of the earth-moon system) and $q = 0$. In the computations for P_{2mp0} the lunar inclination functions $F_{\ell mp}(I_M)$, which change with time due to the motion of the lunar mode, are assumed to take on their average values. Also, $G_{2p0}(e^*)$ is taken to be 1.

Table 5 gives us some insight in determining which tides are important in changing what quantities. It is clear that the M_2 tide governs the rates of change of n_M, a_M, $\dot{\theta}$, and E. The O_1, K_1^M, and M_2 tides appear to be about equally important in changing J and I_s. The table gives the appearance of the M_2 tide governing the change in e_M ; but it is probably the N_2(ℓmpq = 2201) and L_2 (ℓmpq =

220(-1)) tides which dominate the change in the lunar orbital eccentricity. These tides are not given in the table.

APPENDIX 2

We wish to show here how the ocean tides combine with the solid earth tides to give the total tidal potential, as explained by Lambeck, et al. (1974).

The potential of a particular ocean tide constituent n is given by (Lambeck, et al., 1974)

$$U_n = \frac{4\pi G R_E^2}{a} \rho_w \sum_{s,t,u,v} \sum_{+}^{-} \frac{1 + k_s'}{1 + 2s} \left(\frac{R_E}{a}\right)^s C_{nst}^{\pm} F_{stu}(I) G_{suv}(e)$$

$$\cdot \begin{bmatrix} \sin \\ \hline -\cos \end{bmatrix} \left\{ (s - 2u)\omega + (s - 2u + v)M + t(\Omega - \theta) \pm 2\pi n f T + \epsilon_{st}^{\pm} \right\}_{s-t \text{ odd}}^{s-t \text{ even}} .$$

Note that a spherical harmonic in the tide-raising potential excites many spherical harmonics in the ocean tide response; hence the summations in the equation above.

We may simplify the expression above by getting rid of small terms which depend upon the satellite's mean anomaly M and eccentricity e by setting $v = 0$, $G_{su0}(e) \approx 1$, and $s - 2u + v = 0$ (which implies s is even and $u = s/2$). The equation then becomes

$$U_n = \frac{4\pi G R_E^2}{a} \rho_w \sum_{\substack{\text{even } s \\ t}} \sum_{+}^{-} \frac{1 + k_s'}{1 + 2s} \left(\frac{R_E}{a}\right)^s C_{nst}^{\pm} F_{st(s/2)}(I)$$

$$\cdot \begin{bmatrix} \sin \\ \\ -\cos \end{bmatrix} \left\{ t(\Omega - \theta) \pm 2\pi n f T + \epsilon_{st}^{\pm} \right\}_{s-t \text{ odd}}^{s-t \text{ even}}$$

Let us now convert the tidal frequency into orbital elements with the correspondence

$$-2\pi n f T \doteq (\ell - 2p)\omega^* + (\ell - 2p + q) M^* + m(\Omega^* - \theta) - m\pi .$$

The correspondence is not exact (Lambeck, et al., 1973) and more detailed considerations must be given if the period of time under consideration is more than a few years. We now have

$$U_{\ell mpq} = \frac{4\pi G R_E^2}{a} \rho_w \sum_{\substack{\text{even } s \\ t}} \sum_{+}^{-} \frac{1 + k_s'}{1 + 2s} \left(\frac{R_E}{a}\right)^s C^{\pm}_{(\ell mpq)st} F_{st(s/2)}(I)$$

$$\cdot \begin{bmatrix} \sin \\ \\ -\cos \end{bmatrix} \left\{ t(\Omega - \theta) \mp [(\ell - 2p)\omega^* + (\ell - 2p + q)M^* + m(\Omega^* - \theta) - m\pi] + \epsilon^{\pm}_{st} \right\}_{s-t \text{ odd}}^{s-t \text{ even}}$$

where the subscript n has been replaced by (ℓmpq).

Let us now get rid of terms which depend upon the earth's rotation θ. The only way to do this is to pick the plus (+) in $\sum\limits_{+}^{-}$ and set t = m. Then

$$\begin{bmatrix} \sin \\ \\ -\cos \end{bmatrix} \left\{ -[(\ell - 2p)\omega^* + (\ell - 2p + q)M^* + m\Omega^*] - m\Omega + m\pi + \epsilon^{+}_{sm} \right\}_{s-m \text{ odd}}^{s-m \text{ even}}$$

$$= \begin{bmatrix} -\sin \\ \\ \cos \end{bmatrix} \left\{ (\ell - 2p)\omega^* + (\ell - 2p + q)M^* + m\Omega^* - m\Omega - \epsilon^{+}_{sm} \right\}_{m \text{ odd}}^{m \text{ even}}$$

Also $(4\pi/3)\ \bar{\rho}_E R_E^3 = M_E$, so that we may write

$$U_{\ell mpq} = \frac{3GM_E}{R_E^2}\left(\frac{\rho_w}{\bar{\rho}_E}\right) \sum_{\substack{s=2,4,\ldots \\ m}} \frac{1+k_s'}{1+2s} \left(\frac{R_E}{a}\right)^{s+1} C^{+}_{(\ell mpq)\,sm} F_{sm(s/2)}(I)$$

$$\cdot \begin{bmatrix} -\sin \\ \\ \cos \end{bmatrix} \left\{ (\ell - 2p)\omega^* + (\ell - 2p + q) M^* + m\Omega^* - m\Omega - \epsilon^{+}_{sm} \right\} \begin{matrix} m \text{ even} \\ \\ m \text{ odd} \end{matrix}$$

$$= \frac{3GM_E}{R_E^2}\left(\frac{\rho_w}{\bar{\rho}_E}\right) \sum_{\substack{s=2,4,\ldots \\ m}} \left(\frac{1+k_s'}{1+2s}\right) \left(\frac{R_E}{a}\right)^{s+1} C^{+}_{(\ell mpq)\,sm} F_{sm(s/2)}(I)$$

$$\cdot \begin{bmatrix} C^{+}_{(\ell mpq)\,sm} \sin \epsilon^{+}_{sm} \cos \left\{\ \right\} - C^{+}_{(\ell mpq)\,sm} \cos \epsilon^{+}_{sm} \sin \left\{\ \right\} \\ \\ C^{+}_{(\ell mpq)\,sm} \cos \epsilon^{+}_{sm} \cos \left\{\ \right\} + C^{+}_{(\ell mpq)\,sm} \sin \epsilon^{+}_{sm} \sin \left\{\ \right\} \end{bmatrix} \begin{matrix} m \text{ even} \\ \\ m \text{ odd} \end{matrix}$$

where the empty curly brackets mean

$$\left\{\ \right\} = (\ell - 2p)\omega^* + (\ell - 2p + q) M^* + m\Omega^* - m\Omega .$$

Compare this to the solid earth tidal potential, which for $\ell = 2$; $m > 0$; $q = 0$ and small eccentricities is

$$\underset{\text{solid}}{U_{2mp0}} = \frac{2Gm^*}{R_E} \frac{(2-m)!}{(2+m)!} F_{2mp}(I^*) \left(\frac{R_E}{a^*}\right)^3 \left(\frac{R_E}{a}\right)^3 F_{2m1}(I)$$

$$\cdot \left[k_2 \cos \epsilon_{2mp0} \cos \left\{\ \right\} - k_2 \sin \epsilon_{2mp0} \sin \left\{\ \right\} \right].$$

Assuming that the total tidal potential is composed of the solid earth and ocean tides only, one may show from the expressions for the ocean and solid earth tidal potentials that

$$d_{2mp0} \cos \delta_{2mp0} = k_2 \cos \epsilon_{2mp0} + Z_{mp} (1 + k_2') \begin{pmatrix} C^+_{(2mp0)2m} \sin \epsilon^+_{2m} \\ \\ C^+_{(2mp0)2m} \cos \epsilon^+_{2m} \end{pmatrix}^{m \text{ even}}_{m \text{ odd}}$$

$$\left[+ Z_{mp} \cdot 5/9 (1 + k_4') \left(\frac{R_E}{a}\right)^2 \frac{F_{4m2}(I)}{F_{2m1}(I)} \begin{pmatrix} C^+_{(2mp0)4m} \sin \epsilon^+_{4m} \\ \\ C^+_{(2mp0)4m} \cos \epsilon^+_{4m} \end{pmatrix}^{m \text{ even}}_{m \text{ odd}} \right]$$

and

$$d_{2mp0} \sin \delta_{2mp0} = k_2 \sin \epsilon_{2mp0} + Z_{mp} (1 + k_2') \begin{pmatrix} C^+_{(2mp0)2m} \cos \epsilon^+_{2m} \\ \\ -C^+_{(2mp0)2m} \sin \epsilon^+_{2m} \end{pmatrix}^{m \text{ even}}_{m \text{ odd}}$$

$$\left[+ Z_{mp} \cdot 5/9 (1 + k_4') \left(\frac{R_E}{a}\right)^2 \frac{F_{4m2}(I)}{F_{2m1}(I)} \begin{pmatrix} C^+_{(2mp0)4m} \cos \epsilon^+_{4m} \\ \\ -C^+_{(2mp0)4m} \sin \epsilon^+_{4m} \end{pmatrix}^{m \text{ even}}_{m \text{ odd}} \right]$$

where

$$Z_{mp} = 3/10 \frac{(2+m)!}{(2-m)!} \left(\frac{M_E}{m^*}\right) \left(\frac{\rho_w}{\bar{\rho}_E}\right) \left(\frac{a^*}{R_E}\right)^3 \frac{1}{F_{2mp}(I^*) R_E}$$

The term in brackets at the end of each of the above equations for $d_{2mp0} \cos \delta_{2mp0}$ and $d_{2mp0} \sin \delta_{2mp0}$ represents the amount by which the second degree effective

Love numbers and phase angles will be corrupted by the fourth degree ocean tides, if the fourth degree terms are not solved for.

Care must be taken when solving for the effective Love numbers and phase angles of the K_1^M and K_1^S tides. The reason is that the C^+ and ϵ^+ are given for the $K_1 = K_1^M + K_1^S$ tide, and not for the K_1^M and K_1^S tides individually. Some hypothesis is needed to decompose the K_1 into the K_1^M and K_1^S tides. Similar statements hold for the K_2^M and K_2^S tides.

APPENDIX 3

A. PURPOSE

The computer program solves for the effective frequency-dependent tidal Love numbers and phase angles for the whole earth (solid earth + oceans + atmosphere). It does it by performing a multiple regression analysis on the observed tidal perturbation in the inclination of the orbit of an earth satellite. It also solves for ocean tide amplitudes and phases from the Love numbers and lag angles found from the regression analysis, given an assumed tidal response for the solid earth.

All tides are considered to be of second degree only, and only tides which depend on the first power of the orbital eccentricity of the disturbing body are retained; hence the subscripts on the inclination and eccentricity functions run as follows: $\ell = 2$; $m = 1, 2$; $p = 0, 1, 2$; and $q = -1, 0, 1$. Within these limits, any combination of tidal constituents may be chosen to fit the data, giving their effective Love numbers and effective phase angles. Also, the phase angle of any constituent solved for can be set to zero, resulting in a solution for the Love number only for that constituent. There is no restriction on the number of different regression analyses that can be carried out on the data during a run of the program. For example, the sample data cards given in the listing of the main program give two regression analyses.

In practice only the few constituents which give the largest signal in the inclination are fit. If these are not known, then a call to subroutine THEORY gives the theoretical amplitudes and periods of all the constituents in the solid earth signal, given an assumed Love number for the solid earth, such as 0.30. These can be used as a guide for picking out the important constituents. The subroutine also gives a sample plot of inclination vs. time, if this is desired.

The precession of the lunar orbit around the ecliptic requires a certain amount of averaging to be done on the input data for the moon; this is explained in section D. Suffice it to say here that the motion of the lunar node and the moon in its orbit with respect to the earth's equator are average rates over the data span; the inclination of the lunar orbit to the earth's equator is assumed to be constant and equal to its average over the data span. If the data span is longer than four or five years, then a different program taking the precession of the orbit into account more exactly will be needed.

B. THE EXPRESSION FOR THE TIDAL INCLINATION PERTURBATION

The expression for the tidal inclination perturbation is

$$\Delta I = \sum_{m,p,q} \Delta I_{2mpq} + \Delta I_0$$

where

$$\Delta I_{2mpq} = d_{2mpq} \left[2 \frac{(2-m)!}{(2+m)!} \right] m \left[\frac{Gm^*}{\sqrt{GM_E}} \frac{R_E^5}{a^{*3} a^{7/2}} \right] \left[F_{2mp}(I^*) F_{2ml}(I) \right] \left[G_{2pq}(e^*) \right]$$

$$\cdot \left[\frac{1}{\sin I_0}\right] \cos \frac{\left[(2-2p)(\omega^* + M^*) + qM^* + m\Omega^* - m\Omega + \delta_{2mpq}\right]}{\left[(2-2p)(\dot{\omega}^* + \dot{M}^*) + q\dot{M}^* + m\dot{\Omega}^* - m\dot{\Omega}\right]}$$

The program names of the variables in the above equation and in which subroutine they are computed are given below.

Variable	Program Name	Subroutine
d_{2mpq}	YKM(LM,LP,LQ),YKS(LM,LP,LQ)	REGRES,LOVNUM
δ_{2mpq}	EPSLNM(LM,LP,LQ),EPSLNS(LM,LP,LQ)	REGRES,LOVNUM
$2\,\frac{(2-m)!}{(2+m)!}$	B1(LM)	BLM
m	YLM	LOVNUM
$\frac{Gm^*}{\sqrt{GM_E}}\ \frac{R_E^5}{a^{*3}a^{7/2}}$	CFNTM,CFNTS	COEFF
I^*	XIMOON,XISUN	READMS
$F_{2mp}(I^*)$	A1(LM,LP),B(LM,LP)	INCL
I	XI	RDSAT
$F_{2mp}(I)$	C(LM,LP)	INCL
e^*	EMOON,ESUN	ECCFUN
$G_{2pq}(e^*)$	GLPQM(LP,LQ),GLPQS(LP,LQ)	ECCFUN
$\sin I_0$	SS	MAIN
$\dot{\omega}^* + \dot{M}^*$	XNDM,XNDS	READMS,MAIN
$\dot{M}^*$	XMDOTM,XMDOTS	READMS,MAIN

Variable	Program Name	Subroutine
$\dot{\Omega}^*$	OMGDOT	READMS
$\dot{\Omega}$	Q	RDSAT
$(2-2p)(\dot{\omega}^*+\dot{M}^*) + q\dot{M}^* + m\dot{\Omega}^* - m\dot{\Omega}$	ARGDTM(LM,LP,LQ),ARGDTS(LM,LP,LQ)	ARGDOT
$\omega^* + M^*$	XNDM*(TT-TMS)+DELMN, XNDS*(TT-TMS)+DELSUN	READMS,ARG
M^*	XMDOTM*(TT-TMS)+XMEANM, XMDOTS*(TT-TMS)+XMEANS	READMS,ARG
Ω^*	OMGDOT*(TT-TMS)+OMEGAM, OMEGAS	READMS,ARG
Ω	Q*(TT-TZERO)+XNODE	RDSAT,ARG
$\cos \left\{ \; \right\}$	ARGUM(LM,LP,LQ),ARGUS(LM,LP,LQ)	ARG
ΔI_0	ANS(1),XI0	REGRES,LOVNUM

The regression coefficients are found by writing

$$\Delta I_{2mpq} = d_{2mpq} \cos \delta_{2mpq} [\quad] \cos \left\{ (2-2p)(\omega^* + M^*) + qM^* + m\Omega^* - m\Omega \right\}$$

$$-d_{2mpq} \sin \delta_{2mpq} [\quad] \sin \left\{ (2-2p)(\omega^* + M^*) + qM^* + m\Omega^* - m\Omega \right\}$$

so that the data are of the form

$$y_i = \sum_j a_j x_{ij} + b$$

where the regression coefficients a_j are $d_{2mpq} \cos \delta_{2mpq}$ and $-d_{2mpq} \sin \delta_{2mpq}$, and b is ΔI_0, d_{2mpq} and δ_{2mpq} can obviously be solved for from the regression coefficients.

C. BRIEF SUMMARY OF OPERATION

The program begins by reading in the satellite data; the sun and moon data; TSTART, TEND and DT; the assumed solid earth Love number and load deformation coefficient; and the solid earth tidal lag angle. Next, parts of the tidal inclination perturbation are computed. Subroutines TIME1 and CORRES are called, which are used in the plotting and printing of the inclination perturbation and residuals against time.

The program then reads in JTHORY and JPLOT; if JTHORY = 0, then the regression analysis is done wihtout calling subroutine THEORY. If JTHORY = 1, then subroutine THEORY is called but no regression analysis is done. JTHORY = 2 does both. If subroutine THEORY is called and a sample plot of the solid earth signal is desired, then JPLOT should be 1. If no plot of the solid earth signal is desired, then set JPLOT = 0.

The regression analysis begins by calling subroutine LASDTA, which reads in the observed inclination. Subroutine REGRES is then called, which reads data cards to determine what constituents are to be solved for. The comments given in REGRES tell how to pick the constituents. Subroutine REGRES computes the regression coefficients and their errors, prints them and calls subroutine LOVNUM.

Subroutine LOVNUM computes the effective frequency-dependent Love numbers and phase angles and their errors from the regression coefficients and their errors. Then it computes the ocean tide amplitudes and phases from these

by subtracting out the solid earth tide. All of these results are then printed and the inclination and residuals vs. time are printed and plotted.

D. SAMPLE INPUT

The sample input is listed in the main program. Each data card (number) and each number on the data card (letter) are discussed below.

1. The satellite name and when the data were taken are given.

2. a. The semimajor axis of the orbit is 8.07291×10^8 cm.

   b. The eccentricity of the orbit is 0.0726.

   c. The rate at which the node progresses along the earth's equator is -2.246536 degrees/day. This figure is obtained by noting that on Feb. 7, 1966 near the beginning of the data span the node position was -109.08202 degrees, and on Oct. 26, 1967 near the end of the data span the node position was -75.41322 degrees. (All times are 0 hours UT.) Hence the rate is

$$\frac{-1440 + 109.08202 - 75.41322}{626} = -2.246536 \text{ degrees/day}$$

   where the $-1440 = -4(360)$ indicates four complete revolutions of the node.

   d. The inclination of the orbit is 59.38053 degrees with respect to the earth's equator.

e. TZERO is Feb. 7, 1966 12 hrs UT, so TZERO = 38.5.

f. The node position of the satellite at time TZERO was -109.08202 degrees.

The American Ephemeris and Nautical Almanac (Nautical Almanac for short) and Figure 7 are used for obtaining the numbers on the next two data cards.

3. a. The positions of the moon and sun are given for Feb. 4, 1966 in the Nautical Almanac, near the beginning of the data span; hence TMS is taken as TMS = 35.0. On this day the position of the lunar node on the ecliptic was $\Omega = 60.8500$ degrees, according to the Almanac. The position of the lunar node on the earth's equator is found from the formula

$$\tan \Omega^* = \frac{\sin J \sin \Omega}{\sin I \cos J + \cos I \sin J \cos \Omega}$$

where J = 5.1453964 degrees = inclination of the lunar orbit to the ecliptic, and I = 23.44319 degrees = inclination of the ecliptic to the earth's equator. Solving the equation gives $\Omega^* = 10.1770$ degrees.

b. DELTA1 is $\omega^* + M^*$ (measured from the earth's equator); so

$$\mathrm{DELTA1} = \omega^* + M^* = ((- \Omega + c$$

where ((and Ω are given by the Almanac and c is the arc shown in Figure 7. c can be found from the formula

$$\cos c = \frac{\cos I - \cos I^* \cos J}{\sin I^* \sin J}$$

where I*, the inclination of the lunar orbit to the earth's equator is given by

$$\cos I^* = \cos I \cos J - \sin I \sin J \cos \Omega$$

We find that on Feb. 4, 1966 I* = 26.3140 degrees, c = 51.6092 degrees, ((= 115.2340 degrees, and Ω = 60.8500 degrees. Hence DELTA1 = 105.9932 degrees.

c. The nodal position of the sun is always 0.0 degrees.

d. DELTA2 = $\omega^* + M^*$ for the sun is 313.7163 degrees, according to the Almanac.

e. The speed at which the moon moves around in its orbit averaged over the data span is XNDM1 = $\dot{\omega}^* + \dot{M}^*$ = 13.183848 degrees/day. This is found by computing the lunar position on Oct. 27, 1967 at the end of the data span. We find that Ω^* = 5.0417 degrees, I* = 28.1025 degrees, c = 22.9427 degrees, and $\omega^* + M^*$ = 131.8174 degrees. Subtracting this last figure from $\omega^* + M^*$ for Feb. 4, 1966 and making allowance for 23 revolutions of the moon gives

$$\text{XNDM1} = \frac{23(360) + 131.8174 - 105.9932}{630} = 13.183848 \text{ degrees/day.}$$

f. The average speed of the moon's node on the equator is

$$\text{OMGDT1} = \frac{5.0417 - 10.1770}{630} = -0.00815 \text{ degrees/day.}$$

4. a. The inclination of the moon's orbit to the earth's equator averaged over the data span is

$$\text{XID1} = \frac{26.3140 + 28.1025}{2} = 27.2082 \text{ degrees}$$

b. The inclination of the solar orbit to the earth's equator is 23.44319 degrees.

c. TMS is 35.0 days (Feb. 4, 1966).

d. The position of the lunar mean anomaly on Feb. 4, 1966 is $((- \Gamma' =$ 331.5588 degrees, according to the Almanac.

e. The solar mean anomaly on Feb. 4, 1966 is 31.3590 degrees, according to the Almanac.

5. a. TSTART is 37.0 days (Feb. 6, 1966).

b. TEND is 666.0 days (Oct. 28, 1967).

c. DT is 2.0 days.

6. a. The solid earth Love number is taken to be 0.30.

b. The load deformation coefficient of the solid earth is taken to be -0.30.

7. The solid earth tidal lag angle is taken to be 0.0.

8. a. Both the theoretical amplitudes and regression analysis are wanted, so JTHORY = 2.

b. A plot of the theoretical tidal signal is wanted, so JPLOT = 1.

9. a. There are 142 data points.

b. TDAY is 38.5, since this is the date of the first data point and the time on the following cards is measured from the first data point.

10. a. The tidal inclination perturbation of the first data point is -1.1594475 arc seconds.

b. The time of the first data point is 0.0 days.

11. a. The tidal inclination perturbation of the second data point is -0.89708115 arc seconds.

b. The time of the second data point is 13.0 days after the first.

12-151. The rest of the data cards.

152. a. The name of the satellite is GEOS I.

b. There are 142 data points.

c. There are 68 independent variables + 1 dependent variable = 69 variables.

d. Two subset selection cards follow.

153. a. Eight variables are chosen for this regression analysis.

b-i. Fit the K_1 tide (9 and 10), the K_2 tide (27 and 28), the P_1 tide (39 and 40), and the S_2 tide (55 and 56) for effective Love numbers and phase angles.

154. a. Seven variables are chosen for this regression analysis.

b-c. Fit the K_1 and S_2' tides for effective Love numbers and phase angles (9 and 10, 55 and 56).

d-g. Fit the M_2, K_2, and P_1 tides for effective Love numbers but no phase angles (which are forced to be zero).

COMPUTER PROGRAM LISTING

```
C
C
C      MAIN PROGRAM
C
C
C
C
C          THIS PROGRAM SOLVES FOR THE EFFECTIVE FREQUENCY-DEPENDENT TIDAL LOVE
C NUMBERS AND LAG ANGLES FOR THE WHOLE EARTH BY CARRYING OUT A MULTIPLE
C REGRESSION ANALYSIS ON THE TIDAL PERTURBATION IN THE INCLINATION OF THE ORBIT
C OF AN EARTH SATELLITE. IT ALSO SOLVES FOR OCEAN TIDE AMPLITUDES AND PHASES
C FROM THE LOVE NUMBERS AND LAG ANGLES FOUND, GIVEN THE TIDAL RESPONSE OF THE
C SOLID EARTH.
C
C          ONLY 2ND DEGREE TIDES ARE CONSIDERED, AS WELL AS ONLY TERMS WHICH DEPEND
C ON THE FIRST POWER OF ORBITAL ECCENTRICITY  HENCE THE SUBSCRIPTS ON THE
C INCLINATION AND ECCENTRICITY FUNCTIONS RUN AS FOLLOWS  L=2, M=1,2 , P=0,1,2 ,
C AND Q=-1,0,1 . (SINCE THE COMPUTER CANNOT HANDLE ZERO SUBSCRIPTS, IN THIS
C PROGRAM THEY RUN AS FOLLOWS  LM=M, LP=P+1, AND LQ=Q+2 .) WITHIN THESE
C LIMITS, ANY COMBINATION OF TIDAL CONSTITUENTS MAY BE CHOSEN FOR FITTING TO
C THE DATA. IN PRACTICE, ONLY THE FEW CONSTITUENTS WHICH GIVE THE LARGEST SIGNAL
C IN THE INCLINATION ARE FIT. (THE IMPORTANT SIGNALS MAY BE FOUND BY CALLING
C SUBROUTINE THEORY.)
C
C
C          IMPORTANT NOTE  IN THIS PROGRAM  TIDAL INCLINATION PERTURBATION  IS
C          ABBREVIATED  TIP .
C
C
C          BRIEF DESCRIPTION OF EACH SUBROUTINE
C
C          ARG    - COMPUTES THE COSINE TERM IN THE EXPRESSION FOR THE TIP
C          ARGDOT - COMPUTES THE DERIVATIVE OF THE ARGUMENT OF THE COSINE TERM IN
C                   THE TIP
C          ARGLST - COMPUTES SINES AND COSINES TO BE USED IN SUBROUTINE DATA
C          BLM    - COMPUTES THE FACTORIAL TERM IN THE TIP
C          COEFF  - COMPUTES THE COEFFICIENT IN THE TIP OF THE FORM
C                   CONSTANT/(A**7/2)
C          CORRES - USED ONLY BY SUBROUTINE PLOTER TO DETERMINE WHETHER AN
C                   EXPERIMENTAL DATA POINT SHOULD BE PLOTTED AT A PARTICULAR TIME
C          DATA   - COMPUTES VALUES TO BE USED IN REGRESSION ANALYSIS
C          ECCFUN - COMPUTES ECCENTRICITY FUNCTIONS
C          INCL   - COMPUTES INCLINATION FUNCTIONS
C          LAG1   - READS IN SOLID EARTH LAG ANGLE
C          LAG2   - SETS THE FREQUENCY DEPENDENT LAG ANGLES INITIALLY EQUAL TO ZERO
C          LAGDTA - READS IN THE OBSERVED TIP
C          LOVE   - READS IN THE SOLID EARTH LOVE NUMBER AND LOAD DEFORMATION
C                   COEFFICIENT
C          LOVNUM - TAKES THE OUTPUT OF REGRES AND COMPUTES FREQUENCY-DEPENDENT LOVE
C                   NUMBERS, LAG ANGLES, AND OCEAN TIDE PARAMETERS
C          PLOTER - PLOTS OUT THE TIP, EXPERIMENTAL DATA POINTS  AND THE RESIDUALS
C                   ON THE COMPUTER PAPER
C          RDSAT  - READS IN SATELLITE ELEMENTS
C          READMS - READS IN SUN AND MOON POSITIONS, RATES
C          REGRES - PERFORMS REGRESSION ANALYSIS
C          THEORY - COMPUTES AMPLITUDES, PERIODS OF THE SOLID EARTH TIDAL SIGNAL
C          TIME1  - COMPUTES TIME VALUES FOR ARRAY T(L)
C
C
C
C             NOTATION
C
C
C                  SATELLITE
C
C          A                    - SEMIMAJOR AXIS IN 10**8 CM
C          C(LM,LP)             - INCLINATION FUNCTIONS
C          E                    - ORBITAL ECCENTRICITY
C          O                    - RATE OF CHANGE OF NODE POSITION
C          SAT(J)               - ALPHANUMERIC INFORMATION, SUCH AS NAME OF SATELLITE
C          SS                   - SINE OF SATELLITE INCLINATION
C          TZERO                - TIME (MEASURED FROM BEGINNING OF THE YEAR) WHEN THE
C                                 NODE HAD VALUE XNODE
C          XI                   - SATELLITE INCLINATION
C          XNODE                - POSITION OF NODE AT TIME TZERO
C
C                  MOON AND SUN
C
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C       ARGUM(LM,LP,LQ)   - COSINE TERM IN THE TIP
C       ARGUS(LM,LP,LQ)
C
C       ARGDTM(LM,LP,LQ)  - RATE OF CHANGE OF ARGUMENT OF COSINE IN THE TIP
C       ARGDTS(LM,LP,LQ)
C
C       A1(LM,LP)         - INCLINATION FUNCTIONS OF MOON
C       B(LM,LP)
C
C       CFNTM             - TERM IN TIP OF FORM  CONSTANT/(#**7/2)
C       CFNTS
C
C       DELMN             - (ARGUMENT OF PERIGEE + MEAN ANOMALY) OF MOON AT TIME
C                           TMS, MEASURED WITH RESPECT TO EARTH'S EQUATOR
C       DELSUN
C
C       EMOON             - ECCENTRICITY OF LUNAR ORBIT
C       ESUN
C
C       EPSLNM(LM,LP,LQ)  - EFFECTIVE FREQUENCY-DEPENDENT LAG ANGLE FOR LUNAR TIDES
C       EPSLNS(LM,LP,LQ)
C
C       GLPQM(LP,LQ)      - ECCENTRICITY FUNCTION FOR MOON
C       GLPQS(LP,LQ)
C
C       OMEGAM            - POSITION OF LUNAR NODE ON EARTH'S EQUATOR
C       OMEGAS
C
C       XIMOON            - INCLINATION OF LUNAR ORBIT TO EARTH'S EQUATOR
C       XISUN
C
C       XMDOTM            - RATE OF CHANGE OF LUNAR MEAN ANOMALY
C       XMDOTS
C
C       XMOON(LM,LP,LQ)   - LUNAR PART OF TIP
C       XSUN(LM,LP,LQ)
C
C       XNDM              - RATE OF CHANGE OF (ARGUMENT OF PERIGEE + MEAN ANOMALY)
C                           OF MOON, WITH RESPECT TO THE EARTH'S EQUATOR
C       XNDS
C
C       YKM(LM,LP,LQ)     - EFFECTIVE FREQUENCY-DEPENDENT LOVE NUMBER FOR LUNAR
C                           TIDES
C       YKS(LM,LP,LQ)
C
C       TMS               - TIME OF MOON AND SUN POSITIONS
C
C               DATA
C
C       MEXP              - NUMBER OF DATA POINTS
C       TDAY              - CORRECTION TO TEXP(J) TO GIVE IT IN DAYS FROM THE
C                           BEGINNING OF THE YEAR
C       TEXP(J)           - TIME OF OBSERVATION XIEXP(J)
C       XIEXP(J)          - OBSERVED TIP AT TIME TEXP(J)
C
C               MISCELLANEOUS
C
C       DT                - INTERVAL BETWEEN SUCCESSIVE VALUES OF T(L)
C       MT                - TOTAL NUMBER OF VALUES IN ARRAY T(L)
C       T(L)              - TIME VALUES BETWEEN AND INCLUDING TSTART AND TEND
C       TEND              - ENDING TIME OF DATA SPAN
C       TSTART            - STARTING TIME OF DATA SPAN
C       F                 - CONVERSION FACTOR FROM DEGREES TO RADIANS
C       B1(LM)            - FACTORIAL PART OF THE TIP
C       XK                - SOLID EARTH LOVE NUMBER (SECOND DEGREE)
C       XKP               - LOAD DEFORMATION COEFFICIENT (SECOND DEGREE)
C       XI0               - ADDITIVE CONSTANT IN TIP
C       XLAG              - LAG ANGLE OF SOLID EARTH TIDE
C       XINCL(L)          - THE COMPUTED TIP AT TIME T(L)
C       INDEX             - INDEX WHICH KEEPS TRACK OF TIME IN SUBROUTINE DATA
C       NTRACK(L)         - DETERMINES WHETHER A DATA POINT SHOULD BE PLOTTED AT
C                           TIME T(L)
C       TIDE(LM,LP,LQ)    - CONTAINS ALPHANUMERIC NAMES OF TIDES (K1,M2, ETC.)
C       FACTOR            - USED IN SUBROUTINE LOVNUM AS A CORRECTION TO THE
C                           LUNAR TIDES TO GET THE PROPER AMPLITUDE OF THE
C                           LUNISOLAR TIDES
C
C
C
C
```

```
                 C
                 C      SAMPLE INPUT (COLUMN 1 OF THE INPUT STARTS IN COLUMN 3 HERE)
                 C
                 C                 (SAT(J), J=1,14)                              (FORMAT  13A6,A2)
                 C            GEOS - 1   , 1966-1967 DATA
                 C
                 C    A          E           Q1         XI1      TZERO       XNODE1 (FORMAT  8F10.5)
                 C 8.07291    0.0726     -2.246535  59.38053  38.5        -109.0820
                 C
                 C OMEGA1      DELTA1     OMEGA2       DELTA2     XNDM1     OMGDT1 (FORMAT  8F10.5)
                 C 10.1770    105.9932   0.0          313.7163  13.19385  -0.00815
                 C
                 C  XID1        XID2       TMS          XMEAN1      XMEAN2          (FORMAT  8F10.5)
                 C 27.2082    23.44319   35.0         331.5588  31.3590
                 C
                 C TSTART      TEND       DT                                         (FORMAT  8F10.5)
                 C 37.0        666.0      2.0
                 C
                 C  XK          XKP                                                  (FORMAT  8F10.5)
                 C 0.30       -0.30
                 C
                 C  XLAG                                                             (FORMAT  8F10.5)
                 C 0.0
                 C
                 C  JTHORY  JPLOT                                                    (FORMAT  2I5)
                 C     2     1
                 C
                 C  MEXP    TDAY                                                     (FORMAT  I5,F10.5)
                 C   142    38.5
                 C
                 C      XIEXP(J)    TEXP(J)                                          (FORMAT  2D14.8)
                 C -.11594475D 010.0
                 C -.89708115D 000.13        D 02
                 C           ETC.
                 C
                 C PR,PR1     N  M NS
                 C GEOS 1   14269 3
                 C
                 C  K    (ISAVE(J), J=1,K)                                           (FORMAT  36I2)
                 C  8 91027283940555 6
                 C  7 9102127395556
                 C
                 C
                 C
ISN 0002                IMPLICIT REAL*8 (A-H,O-Z)
ISN 0003                DIMENSION EPSLNM(2,3,3),EPSLNS(2,3,3),ARGUM(2,3,3),ARGUS(2,3,3),
                       1 ARGDTM(2,3,3),ARGDTS(2,3,3)
ISN 0004                DIMENSION    E1(2),XMOON(2,3,3),XSUN(2,3,3),YKM(2,3,3),YKS(2,3,3)
ISN 0005                DIMENSION TEXP(200),XIEXP(200),T(700),XINCL(700),NTRACK(700)
ISN 0006                DIMENSION C(2,3),A1(2,3),B(2,3),GLPOM(3,3),GLPOS(3,3)
ISN 0007                COMMON/BLKA/EPSLNM,EPSLNS,ARGUM,ARGUS,ARGDTM,ARGDTS
ISN 0008                COMMON/BLKB/E1,XK,CENTM,CENTS,SUM,XMOON,XSUN,YKM,YKS,XKP
ISN 0009                COMMON/BLKC/TEXP,XIEXP,T,XINCL,NTRACK
ISN 0010                COMMON/BLKD/XLAG,Q,OMEGAM,DELMN,OMEGAS,DELSUN,SS,XIO,A,E,XI,XNODE,
                       1 TZERO,XIMOON,XISUN,TMS,XNDM,XNDS,F,XMEANM,XMEANS,XMDOTM,XMDOTS,
                       2 OMGDOT,MEXP
ISN 0011                COMMON/BLKG/C,A1,B,GLPOM,GLPOS,INDEX
ISN 0012                F=3.14159265400/180.0D0
ISN 0013                XNDS=(0.98564700)*F
ISN 0014                XMDOTM=(13.0649920D0)*F
ISN 0015                XMDOTS=(0.98560D0)*F
                 C READ IN THE DATA, COMPUTE PARTS OF THE TIP
ISN 0016                CALL RDSAT
ISN 0017                CALL READMS
ISN 0018                READ (5,1) TSTART,TEND,DT
ISN 0019        1       FORMAT (8F10.5)
ISN 0020                WRITE (6,7) TSTART,TEND,DT
ISN 0021        7       FORMAT (////////,23X,'TSTART=',F10.4,5X,'TEND=',F10.4,5X,'DT=',
                       1 F10.4,5X,'(DAYS)')
ISN 0022                CALL LOVE
ISN 0023                CALL LAG1
ISN 0024                CALL LAG2
ISN 0025                SS=DSIN(XI)
ISN 0026                CALL ECCFUN
ISN 0027                CALL INCL(XI,C)
ISN 0028                CALL INCL(XIMOON,A1)
ISN 0029                CALL INCL(XISUN,B)
ISN 0030                CALL BLM
ISN 0031                CALL ARGDOT
ISN 0032                CALL COEFF
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ISN 0033          CALL TIME1(TSTART,TEND,DT,MT)
ISN 0034          INDEX=0
ISN 0035          MEXP=0
ISN 0036          CALL CORRES(TSTART,TEND,DT,MEXP)
ISN 0037          READ (5,2) JTHORY,JPLOT
ISN 0038        2 FORMAT (2I5)
            C IF JTHORY=2, CALL THEORY, READ IN DATA POINTS, DC REGRESSION ANALYSIS
            C IF JTHORY=1, CALL THEORY ONLY
            C IF JTHORY=0, READ IN DATA AND DO REGRESSION ANALYSIS WITHOUT CALLING THEORY
            C IF JPLOT=1, THEN A SAMPLE CURVE OF THE TIP WITH SOLID EARTH LOVE NUMBER=XK AND
            C ZERO LAG ANGLE IS PLOTTED BY THEORY
ISN 0039          IF (JTHORY .EQ. 2) GO TO 6
ISN 0041          IF (JTHORY .EQ. 1) GO TO 3
ISN 0043          GO TO 4
ISN 0044        6 CALL THEORY(JPLOT,MT)
ISN 0045          CALL LASDTA
ISN 0046          CALL CORRES(TSTART,TEND,DT,MEXP)
ISN 0047          CALL REGRES(MT)
ISN 0048          GO TO 5
ISN 0049        3 CALL THEORY(JPLOT,MT)
ISN 0050          GO TO 5
ISN 0051        4 CONTINUE
ISN 0052          CALL LASDTA
ISN 0053          CALL CORRES(TSTART,TEND,DT,MEXP)
ISN 0054          CALL REGRES(MT)
ISN 0055        5 CONTINUE
ISN 0056          STOP
ISN 0057          END
```

```
ISN 0002          SUBROUTINE ARG(TT)
            C
            C
            C     THIS SUBROUTINE COMPUTES THE COSINE OF THE ARGUMENT OF THE TIP (I.E. IT
            C COMPUTES THE COSINE OF (L - 2*P)*(ARGUMENT OF PERIGEE+MEAN ANOMALY) + Q* (MEAN
            C ANOMALY) + M*(NODE OF DISTURBING BODY) - M*(NODE OF SATELLITE) + TIDAL LAG
            C ANGLE).
            C
            C
ISN 0003          IMPLICIT REAL*8(A-H,O-Z)
ISN 0004          DIMENSION EPSLNM(2,3,3),EPSLNS(2,3,3),ARGUM(2,3,3),ARGUS(2,3,3),
                 1 ARGDTM(2,3,3),ARGDTS(2,3,3)
ISN 0005          COMMON/BLKA/EPSLNM,EPSLNS,ARGUM,ARGUS,ARGDTM,ARGDTS
ISN 0006          COMMON/BLKD/XLAG,Q,OMEGAM,DELMN,OMEGAS,DELSUN,SS,XI0,A,E,XI,XNODE,
                 1 TZERO,XIMOON,XISUN,TMS,XNDM,XNDS,F,XMEANM,XMEANS,XMDOTM,XMDOTS,
                 2 OMGDOT,MEXP
ISN 0007          DO 10 LM=1,2
ISN 0008          YLM=LM
ISN 0009          DO 10 LP=1,3
ISN 0010          YLP=LP - 1
ISN 0011          DO 10 LQ=1,3
ISN 0012          YLQ=LQ - 2
ISN 0013          A2=(2.0D0 - 2.0D0*YLP)*(XNDM*(TT-TMS)+DELMN) + YLQ*(XMDOTM*(TT-
                 1 TMS)+XMEANM)+YLM*(OMGDOT*(TT-TMS)+OMEGAM) - YLM*(Q*(TT-TZERO)+
                 2 XNODE) + EPSLNM(LM,LP,LQ)
ISN 0014          ARGUM(LM,LP,LQ)=DCOS(A2)
ISN 0015          A3=(2.0D0 - 2.0D0*YLP)*(XNDS*(TT-TMS)+DELSUN) + YLQ*(XMDOTS*(TT-
                 1 TMS)+XMEANS)+ YLM*OMEGAS - YLM*(Q*(TT-TZERO) + XNODE)       +
                 2 EPSLNS(LM,LP,LQ)
ISN 0016          ARGUS(LM,LP,LQ)=DCOS(A3)
ISN 0017       10 CONTINUE
ISN 0018          RETURN
ISN 0019          END
```

```
ISN 0002          SUBROUTINE ARGDOT
            C
            C
            C     THIS SUBROUTINE COMPUTES THE ANGULAR SPEED OF EACH CONSTITUENT (I.E. IS
            C THE TIME DERIVATIVE OF THE ARGUMENT COMPUTED IN SUBROUTINE ARG).
            C
            C
ISN 0003          IMPLICIT REAL*8(A-H,O-Z)
ISN 0004          DIMENSION EPSLNM(2,3,3),EPSLNS(2,3,3),ARGUM(2,3,3),ARGUS(2,3,3),
                 1 ARGDTM(2,3,3),ARGDTS(2,3,3)
ISN 0005          COMMON/BLKA/EPSLNM,EPSLNS,ARGUM,ARGUS,ARGDTM,ARGDTS
ISN 0006          COMMON/BLKD/XLAG,Q,OMEGAM,DELMN,OMEGAS,DELSUN,SS,XI0,A,E,XI,XNODE,
                 1 TZERO,XIMOON,XISUN,TMS,XNDM,XNDS,F,XMEANM,XMEANS,XMDOTM,XMDOTS,
                 2 OMGDOT,MEXP
ISN 0007          DO 10 LM=1,2
ISN 0008          YLM=LM
ISN 0009          DO 10 LP=1,3
ISN 0010          YLP=LP - 1
ISN 0011          DO 10 LQ=1,3
ISN 0012          YLQ=LQ - 2
ISN 0013          ARGDTM(LM,LP,LQ)=(2.0D0 - 2.0D0*YLP)*XNDM +  YLQ*XMDOTM - YLM*Q
                 1 + YLM*OMGDOT
ISN 0014          ARGDTS(LM,LP,LQ)=(2.0D0 - 2.0D0*YLP)*XNDS +  YLQ*XMDOTS - YLM*Q
ISN 0015       10 CONTINUE
ISN 0016          RETURN
ISN 0017          END
```

```
ISN 0002          SUBROUTINE ARGLST(TT)
            C
            C     THIS SUBROUTINE FINDS THE SINE AND COSINE OF (L - 2*P)*(ARGUMENT OF
            C PERIGEE+MEAN ANOMALY) + Q*(MEAN ANOMALY) + M*(NODE OF DISTURBING BODY) -
            C M*(NODE OF SATELLITE) FOR USE IN SUBROUTINE DATA.
            C
            C
ISN 0003          IMPLICIT REAL*8(A-H,O-Z)
ISN 0004          DIMENSION CSM(2,3,3),SNM(2,3,3),CSS(2,3,3),SNS(2,3,3)
ISN 0005          COMMON/BLKD/ XLAG,Q,OMEGAM,DELMN,OMEGAS,DELSUN,SS,XIO,A,E,XI,XNODE,
                 1 TZERO,XIMOON,XISUN,TMS,XNDM,XNDS,F,XMEANM,XMEANS,XMDOTM,XMDOTS,
                 2 OMGDOT,MEXP
ISN 0006          COMMON/BLKF/CSM,SNM,CSS,SNS
ISN 0007          DO 10 LM=1,2
ISN 0008          YLM=LM
ISN 0009          DO 10 LP=1,3
ISN 0010          YLP=LP - 1
ISN 0011          DO 10 LQ=1,3
ISN 0012          YLQ=LQ - 2
ISN 0013          A2=(2.0D0 - 2.0D0*YLP)*(XNDM*(TT-TMS)+DELMN) + YLQ*(XMDOTM*(TT-
                 1 TMS)+XMEANM)+YLM*(OMGDOT*(TT-TMS)+OMEGAM) - YLM*(Q*(TT-TZERO)+
                 2 XNODE)
ISN 0014          CSM(LM,LP,LQ)=DCOS(A2)
ISN 0015          SNM(LM,LP,LQ)=DSIN(A2)
ISN 0016          A3=(2.0D0 - 2.0D0*YLP)*(XNDS*(TT-TMS)+DELSUN) + YLQ*(XMDOTS*(TT-
                 1 TMS)+XMEANS)+ YLM*OMEGAS - YLM*(Q*(TT-TZERO) + XNODE)
ISN 0017          CSS(LM,LP,LQ)=DCOS(A3)
ISN 0018          SNS(LM,LP,LQ)=DSIN(A3)
ISN 0019    10    CONTINUE
ISN 0020          RETURN
ISN 0021          END
```

```
ISN 0002          SUBROUTINE BLM
            C
            C
            C     THIS SUBROUTINE COMPUTES THE FACTORIAL PART OF THE TIP.
            C
            C
            C
ISN 0003          IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004          DIMENSION   B1(2),XMOON(2,3,3),XSUN(2,3,3),YKM(2,3,3),YKS(2,3,3)
ISN 0005          COMMON/BLKB/B1,XK,CENTM,CENTS,SUM,XMOON,XSUN,YKM,YKS,XKP
ISN 0006          B1(1)=1.0D0/3.0D0
ISN 0007          B1(2)=1.0D0/12.0D0
ISN 0008          RETURN
ISN 0009          END
```

```
ISN 0002          SUBROUTINE COEFF
            C
            C
            C     THIS SUBROUTINE COMPUTES THE PART OF THE TIP WHICH HAS THE FORM
            C CONSTANT/(A**7/2).
            C
            C
ISN 0003          IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004          DIMENSION   B1(2),XMOON(2,3,3),XSUN(2,3,3),YKM(2,3,3),YKS(2,3,3)
ISN 0005          COMMON/BLKB/B1,XK,CENTM,CENTS,SUM,XMOON,XSUN,YKM,YKS,XKP
ISN 0006          COMMON/BLKD/ XLAG,Q,OMEGAM,DELMN,OMEGAS,DELSUN,SS,XIO,A,E,XI,XNODE,
                 1 TZERO,XIMOON,XISUN,TMS,XNDM,XNDS,F,XMEANM,XMEANS,XMDOTM,XMDOTS,
                 2 OMGDOT,MEXP
ISN 0007          A2=DSQRT(A)
ISN 0008          CENTM=813.2232D0/((A**3)*A2)
ISN 0009          CENTS=372.9715D0/((A**3)*A2)
ISN 0010          RETURN
ISN 0011          END
```

```
ISN 0002          SUBROUTINE CORRES(TSTART,TEND,DT,MEXP)
            C
            C
            C     THIS SUBROUTINE IS USED ONLY BY SUBROUTINE PLOTER. IT PUTS IN THE VALUES
            C OF ARRAY NTRACK(I), WHICH DETERMINES WHETHER OR NOT AN EXPERIMENTAL DATA POINT
            C SHOULD BE PRINTED AT TIME T(I)  (NTRACK(N)=THE NUMBER OF THE EXPERIMENTAL
            C DATA POINT IF YES, ZERO IF NO.)
            C
            C
ISN 0003          IMPLICIT REAL*8(A-H,O-Z)
ISN 0004          DIMENSION TEXP(200),XIEXP(200),T(700),XINCL(700),NTRACK(700)
ISN 0005          COMMON/BLKC/TEXP,XIEXP,T,XINCL,NTRACK
ISN 0006          MT=(TEND-TSTART)/DT + 1.1D0
ISN 0007          DO 10 I=1,MT
ISN 0008    10    NTRACK(I)=0
ISN 0009          IF (MEXP .EQ. 0) GO TO 12
ISN 0011          DO 11 I=1,MEXP
ISN 0012          N=(TEXP(I)-TSTART)/DT + 1.5D0
ISN 0013          IF (N .LT. 1) N=1
ISN 0015          IF (N .GT. MT) N=MT
ISN 0017    11    NTRACK(N)=I
ISN 0018    12    CONTINUE
ISN 0019          RETURN
ISN 0020          END
```

```
ISN 0002          SUBROUTINE DATA(MM,D)
            C
            C
            C     THIS SUBROUTINE IS USED TO FEED IN DATA FOR USE IN THE MULTIPLE
            C REGRESSION ANALYSIS CARRIED OUT BY SUBROUTINE REGRES.
            C
            C
ISN 0003          IMPLICIT REAL*8(A-H,O-Z)
ISN 0004          REAL*4 D(MM)
ISN 0005          DIMENSION EPSLNM(2,3,3),EPSLNS(2,3,3),ARGUM(2,3,3),ARGUS(2,3,3),
                 1 ARGDTM(2,3,3),ARGDTS(2,3,3)
ISN 0006          DIMENSION    B1(2),XMOON(2,3,3),XSUN(2,3,3),YKM(2,3,3),YKS(2,3,3)
ISN 0007          DIMENSION TEXP(200),XIEXP(200),T(700),XINCL(700),NTRACK(700)
ISN 0008          DIMENSION C(2,3),A1(2,3),B(2,3),GLPQM(3,3),GLPQS(3,3)
ISN 0009          DIMENSION CSM(2,3,3),SNM(2,3,3),CSS(2,3,3),SNS(2,3,3)
ISN 0010          COMMON/BLKA/EPSLNM,EPSLNS,ARGUM,ARGUS,ARGDTM,ARGDTS
ISN 0011          COMMON/BLKB/B1,XK,CENTM,CENTS,SUM,XMOON,XSUN,YKM,YKS,XKP
ISN 0012          COMMON/BLKC/TEXP,XIEXP,T,XINCL,NTRACK
ISN 0013          COMMON/BLKD/XLAG,Q,OMEGAM,DELMN,OMEGAS,DELSUN,SS,XI0,A,E,XI,XNODE,
                 1 TZERO,XIMOON,XISUN,TMS,XNDM,XNDS,F,XMEANM,XMEANS,XMDOTM,XMDOTS,
                 2 OMGDOT,MEXP
ISN 0014          COMMON/BLKF/CSM,SNM,CSS,SNS
ISN 0015          COMMON/BLKG/C,A1,B,GLPQM,GLPQS,INDEX
            C INDEX IS USED TO KEEP TRACK OF TIME
ISN 0016          INDEX=INDEX + 1
ISN 0017          TT=TEXP(INDEX)
ISN 0018          CALL ARGLST(TT)
            C DO THE LUNAR TIDES. WE LUMP THE LUNISOLAR TIDES WITH THE LUNAR TIDES.
ISN 0019          I=0
ISN 0020          DO 70 LM=1,2
ISN 0021          YLM=LM
ISN 0022          DO 70 LP=1,3
ISN 0023          DO 70 LQ=1,3
ISN 0024          I=I + 1
ISN 0025          D(I)=CENTM*B1(LM)*C(LM,2)*A1(LM,LP)*GLPQM(LP,LQ)*YLM*CSM(LM,LP,LQ)
                 1/(ARGDTM(LM,LP,LQ)*SS)
ISN 0026          I=I + 1
ISN 0027          D(I)=CENTM*B1(LM)*C(LM,2)*A1(LM,LP)*GLPQM(LP,LQ)*YLM*SNM(LM,LP,LQ)
                 1/(ARGDTM(LM,LP,LQ)*SS)
ISN 0028     70   CONTINUE
            C DO THE SOLAR TIDES
ISN 0029          DO 71 LM=1,2
ISN 0030          YLM=LM
ISN 0031          DO 71 LP=1,3
ISN 0032          DO 71 LQ=1,3
ISN 0033          IF (LP .EQ. 2 .AND. LQ .EQ. 2) GO TO 71
ISN 0035          I=I + 1
ISN 0036          D(I)=CENTS*B1(LM)*C(LM,2)*B(LM,LP)*GLPQS(LP,LQ)*YLM*CSS(LM,LP,LQ)/
                 1 (ARGDTS(LM,LP,LQ)*SS)
ISN 0037          I=I + 1
ISN 0038          D(I)=CENTS*B1(LM)*C(LM,2)*B(LM,LP)*GLPQS(LP,LQ)*YLM*SNS(LM,LP,LQ)/
                 1 (ARGDTS(LM,LP,LQ)*SS)
ISN 0039     71   CONTINUE
            C PUT IN OBSERVED INCLINATION
ISN 0040          I=I + 1
ISN 0041          D(I)=XIEXP(INDEX)
ISN 0042          RETURN
ISN 0043          END


ISN 0002          SUBROUTINE ECCFUN
            C
            C
            C     THIS SUBROUTINE COMPUTES THE ECCENTRICITY FUNCTIONS FOR THE MOON AND SUN.
            C
            C
ISN 0003          IMPLICIT REAL*8(A-H,O-Z)
ISN 0004          DIMENSION C(2,3),A1(2,3),B(2,3),GLPQM(3,3),GLPQS(3,3)
ISN 0005          COMMON/BLKG/C,A1,B,GLPQM,GLPQS,INDEX
ISN 0006          EMOON=0.0549D0
ISN 0007          GLPQM(1,1)=(-0.5D0)*EMOON
ISN 0008          GLPQM(1,2)=1.0D0
ISN 0009          GLPQM(1,3)=(3.5D0)*EMOON
ISN 0010          GLPQM(2,1)=(1.5D0)*EMOON
ISN 0011          GLPQM(2,2)=1.0D0
ISN 0012          GLPQM(2,3)=(1.5D0)*EMOON
ISN 0013          GLPQM(3,1)=(3.5D0)*EMOON
ISN 0014          GLPQM(3,2)=1.0D0
ISN 0015          GLPQM(3,3)=(-0.5D0)*EMOON
ISN 0016          ESUN=0.0167D0
ISN 0017          GLPQS(1,1)=(-0.5D0)*ESUN
ISN 0018          GLPQS(1,2)=1.0D0
ISN 0019          GLPQS(1,3)=(3.5D0)*ESUN
ISN 0020          GLPQS(2,1)=(1.5D0)*ESUN
ISN 0021          GLPQS(2,2)=1.0D0
ISN 0022          GLPQS(2,3)=(1.5D0)*ESUN
ISN 0023          GLPQS(3,1)=(3.5D0)*ESUN
ISN 0024          GLPQS(3,2)=1.0D0
ISN 0025          GLPQS(3,3)=(-0.5D0)*ESUN
ISN 0026          RETURN
ISN 0027          END
```

```
ISN 0002          SUBROUTINE INCL(XI,F)
            C
            C
            C     THIS SUBROUTINE COMPUTES THE SECOND DEGREE INCLINATION FUNCTIONS.
            C
            C
ISN 0003          IMPLICIT REAL*8(A-H,O-Z)
ISN 0004          DIMENSION F(2,3)
ISN 0005          S=DSIN(XI)
ISN 0006          C=DCOS(XI)
ISN 0007          S2=S**2
ISN 0008          C2=C**2
ISN 0009          F(1,1)=(3.0D0/4.0D0)*S*(1.0D0 + C)
ISN 0010          F(1,2)=(-3.0D0/2.0D0)*S*C
ISN 0011          F(1,3)=(-3.0D0/4.0D0)*S*(1.0D0 - C)
ISN 0012          F(2,1)=(3.0D0/4.0D0)*((1.0D0 + C)**2)
ISN 0013          F(2,2)=(3.0D0/2.0D0)*S2
ISN 0014          F(2,3)=(3.0D0/4.0D0)*((1.0D0 - C)**2)
ISN 0015          RETURN
ISN 0016          END
```

```
ISN 0002          SUBROUTINE LAG1
            C
            C
            C     THIS SUBROUTINE READS IN THE SOLID EARTH LAG ANGLE XLAG AND CONVERTS IT
            C FROM DEGREES TO RADIANS.
            C
            C
ISN 0003          IMPLICIT REAL*8(A-H,O-Z)
ISN 0004          COMMON/BLKD/XLAG,Q,OMEGAM,DELMN,OMEGAS,DELSUN,SS,XIO,A,E,XI,XNODE,
                 1 TZERO,XIMOON,XISUN,TMS,XNDM,XNDS,F,XMEANM,XMEANS,XMDOTM,XMDOTS,
                 2 OMGDOT,MEXP
ISN 0005          READ (5,1) XLAG
ISN 0006     1    FORMAT (8F10.5)
ISN 0007          WRITE (6,2) XLAG
ISN 0008     2    FORMAT (////////,23X,'SOLID EARTH LAG ANGLE=',F8.3,1X,'DEGREES')
ISN 0009          XLAG=XLAG*F
ISN 0010          RETURN
ISN 0011          END
```

```
ISN 0002          SUBROUTINE LAG2
            C
            C
            C     THIS SUBROUTINE SETS THE FREQUENCY DEPENDENT TIDAL LAG ANGLES INITIALLY
            C EQUAL TO ZERO.
            C
            C
ISN 0003          IMPLICIT REAL*8(A-H,O-Z)
ISN 0004          DIMENSION EPSLNM(2,3,3),EPSLNS(2,3,3),ARGUM(2,3,3),ARGUS(2,3,3),
                 1 ARGDTM(2,3,3),ARGDTS(2,3,3)
ISN 0005          COMMON/BLKA/EPSLNM,EPSLNS,ARGUM,ARGUS,ARGDTM,ARGDTS
ISN 0006          COMMON/BLKD/XLAG,Q,OMEGAM,DELMN,OMEGAS,DELSUN,SS,XIO,A,E,XI,XNODE,
                 1 TZERO,XIMOON,XISUN,TMS,XNDM,XNDS,F,XMEANM,XMEANS,XMDOTM,XMDOTS,
                 2 OMGDOT,MEXP
ISN 0007          DO 10 LM=1,2
ISN 0008          DO 10 LP=1,3
ISN 0009          DO 10 LQ=1,3
ISN 0010          EPSLNM(LM,LP,LQ)=0.0D0
ISN 0011          EPSLNS(LM,LP,LQ)=0.0D0
ISN 0012    10    CONTINUE
ISN 0013          RETURN
ISN 0014          END
```

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      SUBROUTINE LASDTA
C
C
C     THIS SUBROUTINE READS IN, THEN PRINTS OUT, THE OBSERVED TIP. XIEXP(J) IS
C THE OBSERVED TIP (IN ARCSECONDS) AT TIME TEXP(J) (IN DAYS).
C     TDAY IS A CORRECTION FACTOR, WHICH MAKES TEXP(J) START AT THE BEGINNING OF
C THE YEAR (JAN 1 AT 0 HRS UT = 1 ). TDAY IS NECESSARY SINCE OFTENTIMES THE
C TIME OF EACH DATA POINT IS GIVEN IN DAYS AFTER THE FIRST OBSERVATION (I.E.
C TEXP(1)=0.0 ).
C
C
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION TEXP(200),XIEXP(200),T(700),XINCL(700),NTRACK(700)
      COMMON/BLKC/TEXP,XIEXP,T,XINCL,NTRACK
      COMMON/BLKD/XLAG,Q,OMEGAM,DELMN,OMEGAS,DELSUN,SS,XIO,A,E,XI,XNODE,
     1 TZERO,XIMOON,XISUN,TMS,XNDM,XNDS,F,XMEANM,XMEANS,XMDOTM,XMDOTS,
     2 OMGDOT,MEXP
      READ (5,33) MEXP,TDAY
   33 FORMAT (I5,F10.5)
      DO 32 J=1,MEXP
      READ (5,34) XIEXP(J),TEXP(J)
      TEXP(J)=TEXP(J) + TDAY
   32 CONTINUE
   34 FORMAT (2D14.6)
      WRITE (6,2)
    2 FORMAT (1H1)
      WRITE (6,3)
    3 FORMAT (/////,50X,'SATELLITE TRACKING DATA',////)
      WRITE (6,15) MEXP,TDAY
   15 FORMAT (41X,'(',I5,' DATA POINTS, TDAY=',F8.4,' DAYS)',////)
      WRITE (6,4)
    4 FORMAT (48X,'TIME',13X,'INCLINATION',/)
      WRITE (6,5)
    5 FORMAT (47X,'(DAYS)',14X,'(ARCSEC)')
      WRITE (6,16)
   16 FORMAT (38X,'(JAN 1, 0 HRS UT = 1)',//)
      DO 10 J=1,MEXP
   10 WRITE (6,11) J,TEXP(J),XIEXP(J)
   11 FORMAT (35X,I5,5X,F10.4,10X,F10.4)
      RETURN
      END
```

```
      SUBROUTINE LOVE
C
C
C     THIS SUBROUTINE READS IN THE SECOND DEGREE LOVE NUMBER AND LOAD
C DEFORMATION COEFFICIENT OF THE SOLID EARTH.
C
C
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION   B1(2),XMOON(2,3,3),XSUN(2,3,3),YKM(2,3,3),YKS(2,3,3)
      COMMON/BLKB/B1,XK,CENTM,CENTS,SUM,XMOON,XSUN,YKM,YKS,XKP
      READ (5,1) XK,XKP
    1 FORMAT (8F10.5)
      WRITE (6,2) XK,XKP
    2 FORMAT (////////,23X,'SOLID EARTH LOVE NUMBER=',F8.4,10X,'LOAD DEF
     1ORMATION COEFFICIENT=',F8.4)
      RETURN
      END
```

```
ISN 0002          SUBROUTINE LOVNUM(MT)
             C
             C
             C     THIS SUBROUTINE TAKES THE COEFFICIENTS AND THEIR ERRORS FOUND IN
             C   SUBROUTINE REGRES AND SOLVES FOR THE FREQUENCY DEPENDENT LOVE NUMBERS, TIDAL
             C   LAG ANGLES, AND THEIR ERRORS. IT ALSO FINDS THE OCEAN TIDE PARAMETERS,
             C   ASSUMING THE SOLID EARTH LOVE NUMBER AND LAG ANGLE ARE KNOWN.
             C*****ALL TIDES ARE ASSUMED TO BE 2ND DEGREE ONLY. HENCE ALL OTHER TIDES ARE
             C   ABSORBED INTO THE 2ND DEGREE TIDES.
             C
             C
ISN 0003          IMPLICIT REAL*8(A-H,O-Z)
ISN 0004          REAL*4 VV(70),VE(70),ANS(10)
ISN 0005          DIMENSION EPSLNM(2,3,3),EPSLNS(2,3,3),ARGUM(2,3,3),ARGUS(2,3,3),
                 1 ARGDTM(2,3,3),ARGDTS(2,3,3)
ISN 0006          DIMENSION    B1(2),XMOON(2,3,3),XSUN(2,3,3),YKM(2,3,3),YKS(2,3,3)
ISN 0007          DIMENSION TEXP(200),XIEXP(200),T(700),XINCL(700),NTRACK(700)  .
ISN 0008          DIMENSION C(2,3),A1(2,3),B(2,3),GLPOM(3,3),GLPOS(3,3)
ISN 0009          DIMENSION NN(70),ISAVE(70)
ISN 0010          DIMENSION TIDE(2,3,3)
ISN 0011          DIMENSION SAT(14)
ISN 0012          COMMON/BLKA/EPSLNM,EPSLNS,ARGUM,ARGUS,ARGDTM,ARGDTS
ISN 0013          COMMON/BLKB/B1,XK,CENTM,CENTS,SUM,XMOON,XSUN,YKM,YKS,XKP
ISN 0014          COMMON/BLKC/TEXP,XIEXP,T,XINCL,NTRACK
ISN 0015          COMMON/BLKD/XLAG,Q,OMEGAM,DELMN,OMEGAS,DELSUN,SS,XIO,A,E,XI,XNODE,
                 1 TZERO,XIMOON,XISUN,TMS,XNOM,XNOS,F,XMEANM,XMEANS,XMDOTM,XMDOTS,
                 2 OMGDOT,MEXP
ISN 0016          COMMON/BLKG/C,A1,B,GLPOM,GLPOS,INDEX
ISN 0017          COMMON/BLKH/VV,VE,ANS,ISAVE,M,K
ISN 0018          COMMON/BLKI/SAT
ISN 0019          DATA BLANK/4H    /
ISN 0020          DATA TM112,TM122,TM212,TM222/4HO1  ,4HK1  ,4HM2  ,4HK2  /
ISN 0021          DATA TS112,TS122,TS212,TS222/4HP1  ,4HK1S ,4HS2  ,4HK2S /
ISN 0022          PI=3.14159265359D0
ISN 0023          YLAG=XLAG/F
             C  SET THE ADDITIVE CONSTANT IN THE TIP EQUAL TO XIO
ISN 0024          XIO=ANS(1)
ISN 0025          WRITE (6,19)
ISN 0026     19   FORMAT (1H1)
             C  PRINT OUT THE HEADINGS
ISN 0027          WRITE (6,81)
ISN 0028     81   FORMAT (25X,'*****FREQUENCY DEPENDENT LOVE NUMBERS*****',10X,
                 1 '*****OCEAN TIDE PARAMETERS*****')
ISN 0029          WRITE (6,82)
ISN 0030     82   FORMAT (30X,'(ASSUMING 2ND DEGREE TIDES ONLY)'17X,'(ASSUMING 2ND
                 1DEGREE TIDES')
ISN 0031          WRITE (6,83)
ISN 0032     83   FORMAT (79X,'ONLY AND SOLID EARTH LOVE')
ISN 0033          WRITE (6,84) XK
ISN 0034     84   FORMAT (79X,'NUMBER K2=',F5.3,1X,'AND SOLID')
ISN 0035          WRITE (6,85) YLAG
ISN 0036     85   FORMAT (79X,'EARTH TIDAL LAG=',F5.3,1X,'DEG)',/)
ISN 0037          WRITE (6,40)
ISN 0038     40   FORMAT (1X,'L M P Q  TIDE  DIS.BODY  LOVE NUMBER  STD. ERROR  LAG
                 1ANGLE  STD. ERROR         C        STD. ERROR    PHASE    STD. ERROR
                 2')
ISN 0039          WRITE (6,39)
ISN 0040     39   FORMAT (51X,'(DEGREES)',3X,'(DEGREES)',7X,'(CM)',9X,'(CM)',3X,
                 1 '(DEGREES)',4X,'(DEGREES)',/)
             C  SET NN(J) =0 FOR TIDES NOT SOLVED FOR BY THE MULTIPLE REGRESSION IN
             C  SUBROUTINE REGRES, AND NN(J)=1 FOR THOSE WHICH ARE SOLVED FOR
ISN 0041          MV=M - 1
ISN 0042          DO 20 J=1,MV
ISN 0043     20   NN(J)=0
ISN 0044          DO 21 J=1,K
ISN 0045          ISS=ISAVE(J)
ISN 0046     21   NN(ISS)=1
             C
             C*****LUNAR AND LUNISOLAR TIDES*****
             C
             C  PUT NAME OF TIDAL CONSTITUENT IN ARRAY TIDE
ISN 0047          DO 89 LM=1,2
ISN 0048          DO 89 LP=1,3
ISN 0049          DO 89 LQ=1,3
ISN 0050     89   TIDE(LM,LP,LQ)=BLANK
ISN 0051          TIDE(1,1,2)=TM112
ISN 0052          TIDE(1,2,2)=TM122
ISN 0053          TIDE(2,1,2)=TM212
```

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ISN 0054          TIDE(2,2,2)=TM222
ISN 0055          LLL=2
ISN 0056          I=0
ISN 0057          DO 60 LM=1,2
ISN 0058          YLM=LM
ISN 0059          DO 60 LP=1,3
ISN 0060          YLP=LP - 1
ISN 0061          LPP=LP - 1
ISN 0062          DO 60 LQ=1,3
ISN 0063          LQQ=LQ - 2
ISN 0064          I=I + 1
ISN 0065          U1=VV(I)
ISN 0066          E1=VE(I)
ISN 0067          I3=I
ISN 0068          I= I + 1
ISN 0069          U2=-VV(I)
ISN 0070          E2=VE(I)
            C  IF ONLY THE EFFECTIVE LOVE NUMBER IS SOLVED FOR, PUT THE EFFECTIVE LAG ANGLE
            C  AND ITS ERROR EQUAL TO ZERO
ISN 0071          IF (NN(I) .EQ. 0) U2=0.0D0
ISN 0073          IF (NN(I) .EQ. 0) E2=0.0D0
            C  IF THIS TIDE WAS NOT SOLVED FOR, GO TO 62
ISN 0075          IF (NN(I3) .EQ. 0 .AND. NN(I) .EQ. 0) GO TO 62
ISN 0077          U3=U1**2 + U2**2
            C  FIND THE EFFECTIVE FREQUENCY-DEPENDENT LOVE NUMBER
ISN 0078          YKM(LM,LP,LQ)=DSQRT(U3)
ISN 0079          U4=U2/U1
            C  FIND THE EFFECTIVE FREQUENCY-DEPENDENT LAG ANGLE, MAKING SURE WE KNOW WHICH
            C  QUADRANT IT IS IN
ISN 0080          EPSLNM(LM,LP,LQ)=DATAN(U4)
ISN 0081          IF (U4) 22,28,23
ISN 0082      28  CONTINUE
ISN 0083          IF (U1) 29,27,27
ISN 0084      29  EPSLNM(LM,LP,LQ)=PI
ISN 0085          GO TO 27
ISN 0086      22  CONTINUE
ISN 0087          IF (U2) 25,24,24
ISN 0088      24  EPSLNM(LM,LP,LQ)=EPSLNM(LM,LP,LQ) + PI
ISN 0089      25  CONTINUE
ISN 0090          GO TO 27
ISN 0091      23  CONTINUE
ISN 0092          IF (U2) 26,27,27
ISN 0093      26  EPSLNM(LM,LP,LQ)=EPSLNM(LM,LP,LQ) + PI
ISN 0094      27  CONTINUE
            C  EP IS THE EFFECTIVE TIDAL LAG ANGLE IN DEGREES
ISN 0095          EP=EPSLNM(LM,LP,LQ)/F
ISN 0096          SIGSQR=((E1**2)*(U1**2) + (E2**2)*(U2**2))/U3
            C  SIGLOV IS THE STD. ERROR OF YKM(LM,LP,LQ)
ISN 0097          SIGLOV=DSQRT(SIGSQR)
ISN 0098          SIGSQR=((E2**2)*(U1**2) + (E1**2)*(U2**2))/(U3**2)
            C  SIGLAG IS THE STD. ERROR OF EPSLNM(LM,LP,LQ) IN DEGREES
ISN 0099          SIGLAG=DSQRT(SIGSQR)/F
            C
            C FACTOR TAKES CARE OF THE AMPLITUDE OF THE LUNISOLAR TIDES. REMEMBER, THE
            C LUNISOLAR TIDES ARE LUMPED WITH THE LUNAR TIDES IN SUBROUTINE DATA  HENCE A
            C CORRECTION MUST BE APPLIED TO THE LUNAR TIDES WHEN THE LUNISOLAR CASE COMES
            C UP. SYMBOLICALLY, FACTOR=(1 + SUN/MOON)*MOON = MOON + SUN, AS IT SHOULD FOR
            C THE LUNISOLAR TIDES.
            C
ISN 0100          FACTOR=1.0D0 + (CENTS*B(LM,2))/(CENTM*A1(LM,LP))
            C
            C  DO THE OCEAN TIDES
            C
            C YM*XLAG IS THE LAG ANGLE OF THE SOLID EARTH CONVERTED TO FREQUENCY-DEPENDENT
            C FORM
ISN 0101          YM=LM
ISN 0102          CXLAG=DCOS(YM*XLAG)
ISN 0103          SXLAG=DSIN(YM*XLAG)
            C  SUBTRACT OUT THE SOLID EARTH TIDE
ISN 0104          SEA1=U1 - XK*CXLAG
ISN 0105          IF (LP .EQ. 2 .AND. LQ .EQ. 2) SEA1=U1 - FACTOR*XK*CXLAG
ISN 0107          SEA2=U2 - XK*SXLAG
ISN 0108          IF (LP .EQ. 2 .AND. LQ .EQ. 2) SEA2=U2 - FACTOR*XK*SXLAG
ISN 0110          SEA3=SEA1**2 + SEA2**2
ISN 0111          SEA5=DSQRT(SEA3)
            C  FIND COCEAN, THE OCEAN AMPLITUDE
ISN 0112          COCEAN=(320.0379SD00)*SEA5*B1(LM)*A1(LM,LP)/(1.0D0 + XKP)
ISN 0113          SIGSQR=((E1**2)*(SEA1**2) + (E2**2)*(SEA2**2))/SEA3
ISN 0114          SIG=DSQRT(SIGSQR)
            C  SIGC IS THE STD. ERROR OF COCEAN
```

```
ISN 0115            SIGC=(320.03795D0)*SIG*B1(LM)*DABS(A1(LM,LP))/(1.0D0 + XKP)
ISN 0116            SIGSQR=((E2**2)*(SEA1**2) + (E1**2)*(SEA2**2))/(SEA3**2)
              C  SIGPHS IS THE STD. ERROR OF THE PHASE ANGLE IN DEGREES
ISN 0117            SIGPHS=DSQRT(SIGSQR)/F
ISN 0118            U44=SEA2/SEA1
              C  FIND THE PHASE ANGLE OF THE OCEAN TIDE, MAKING SURE WE KNOW WHICH QUADRANT
              C  IT IS IN
ISN 0119            PHASE=DATAN(U44)
ISN 0120            IF (U44) 42,48,43
ISN 0121        48  CONTINUE
ISN 0122            IF (SEA1) 49,47,47
ISN 0123        49  PHASE=PI
ISN 0124            GO TO 47
ISN 0125        42  CONTINUE
ISN 0126            IF (SEA2) 45,44,44
ISN 0127        44  PHASE=PHASE + PI
ISN 0128        45  CONTINUE
ISN 0129            GO TO 47
ISN 0130        43  CONTINUE
ISN 0131            IF (SEA2) 46,47,47
ISN 0132        46  PHASE=PHASE + PI
ISN 0133        47  CONTINUE
ISN 0134            PHASE=-PHASE + (YM - 1.0D0)*(PI/2.0D0)
              C  INSURE THAT COCEAN IS A POSITIVE AMPLITUDE
ISN 0135            IF (COCEAN) 51,50,50
ISN 0136        51  COCEAN=-COCEAN
ISN 0137            PHASE=PHASE - PI
ISN 0138        50  CONTINUE
              C  CONVERT PHASE FROM RADIANS TO DEGREES
ISN 0139            PHASE=PHASE/F
ISN 0140            IF (PHASE) 90,91,91
ISN 0141        90  PHASE=PHASE+360.0
ISN 0142        91  CONTINUE
ISN 0143            IF (PHASE) 92,93,93
ISN 0144        92  PHASE=PHASE+360.0
ISN 0145        93  CONTINUE
ISN 0146            IF (LP .EQ. 2 .AND. LQ .EQ. 2) GO TO 67
              C  PRINT OUT L,M,P,Q, CONSTITUENT, DISTURBING BODY, FREQUENCY DEPENDENT LOVE
              C  NUMBER AND ITS ERROR, LAG ANGLE AND ITS ERROR, OCEAN AMPLITUDE AND ITS
              C  ERROR, PHASE ANGLE AND ITS ERROR
ISN 0148            WRITE (6,63) LLL,LM,LPP,LQQ,TIDE(LM,LP,LQ),YKM(LM,LP,LQ),SIGLOV,EP
                   1,SIGLAG,COCEAN,SIGC,PHASE,SIGPHS
ISN 0149        63  FORMAT (4I2,2X,A4,4X,'MOON',5X,F10.5,2X,F10.5,2X,F9.5,3X,F9.5,
                   1 4X,F10.5,2X,F10.5,2X,F9.4,2X,F9.4)
ISN 0150            GO TO 69
ISN 0151        67  XLVNUM=YKM(LM,LP,LQ)/FACTOR
ISN 0152            SIGLOV=SIGLOV/FACTOR
ISN 0153            WRITE (6,68) LLL,LM,LPP,LQQ,TIDE(LM,LP,LQ),XLVNUM,SIGLOV,EP,SIGLAG
                   1,COCEAN,SIGC,PHASE,SIGPHS
ISN 0154        68  FORMAT (4I2,2X,A4,2X,'MOON+SUN',3X,F10.5,2X,F10.5,2X,F9.5,3X,F9.5,
                   1 4X,F10.5,2X,F10.5,2X,F9.4,2X,F9.4)
ISN 0155        69  CONTINUE
ISN 0156            GO TO 60
ISN 0157        62  CONTINUE
              C  SET THE LOVE NUMBER AND LAG ANGLE TO ZERO FOR TIDES NOT SOLVED FOR
ISN 0158            YKM(LM,LP,LQ)=0.0D0
ISN 0159            EPSLNM(LM,LP,LQ)=0.0D0
ISN 0160            IF (LP .EQ. 2 .AND. LQ .EQ. 2) GO TO 7
ISN 0162            WRITE (6,8) LLL,LM,LPP,LQQ,TIDE(LM,LP,LQ)
ISN 0163         8  FORMAT (4I2,2X,A4,4X,'MOON',12X,'...',9X,'...',8X,'...',9X,'...',
                   1 11X,'...',9X,'...',8X,'...',8X,'...')
ISN 0164            GO TO 6
ISN 0165         7  WRITE (6,5) LLL,LM,LPP,LQQ,TIDE(LM,LP,LQ)
ISN 0166         5  FORMAT (4I2,2X,A4,2X,'MOON+SUN',10X,'...',9X,'...',8X,'...',9X,
                   1 '...',11X,'...',9X,'...',8X,'...',8X,'...')
ISN 0167         6  CONTINUE
ISN 0168        60  CONTINUE
ISN 0169            WRITE (6,18)
ISN 0170        18  FORMAT (10X,////)
              C
              C*****SOLAR TIDES*****
              C
              C  PUT NAME OF TIDAL CONSTITUENT IN ARRAY TIDE
ISN 0171            DO 88 LM=1,2
ISN 0172            DO 88 LP=1,3
ISN 0173            DO 88 LQ=1,3
ISN 0174        88  TIDE(LM,LP,LQ)=BLANK
ISN 0175            TIDE(1,1,2)=TS112
ISN 0176            TIDE(1,2,2)=TS122
ISN 0177            TIDE(2,1,2)=TS212
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ISN 0178          TIDE(2,2,2)=TS222
ISN 0179          DO 65 LM=1,2
ISN 0180          YLM=LM
ISN 0181          DO 65 LP=1,3
ISN 0182          YLP=LP - 1
ISN 0183          LPP=LP - 1
ISN 0184          DO 65 LQ=1,3
ISN 0185          LQQ=LQ - 2
ISN 0186          IF (LP .EQ. 2 .AND. LQ .EQ. 2) GO TO 66
ISN 0188          I=I + 1
ISN 0189          U1=VV(I)
ISN 0190          E1=VE(I)
ISN 0191          I3=I
ISN 0192          I=I + 1
ISN 0193          U2=-VV(I)
ISN 0194          E2=VE(I)
            C  IF ONLY THE EFFECTIVE LOVE NUMBER IS SOLVED FOR, PUT THE EFFECTIVE LAG ANGLE
            C  AND ITS ERROR EQUAL TO ZERO
ISN 0196          IF (NN(I) .EQ. 0) U2=0.0D0
ISN 0197          IF (NN(I) .EQ. 0) E2=0.0D0
            C  IF THIS TIDE WAS NOT SOLVED FOR, GO TO 66
ISN 0199          IF (NN(I3) .EQ. 0 .AND. NN(I) .EQ. 0) GO TO 66
ISN 0201          U3=U1**2 + U2**2
            C  FIND THE EFFECTIVE FREQUENCY-DEPENDENT LOVE NUMBER
ISN 0202          YKS(LM,LP,LQ)=DSQRT(U3)
ISN 0203          U4=U2/U1
            C  FIND THE EFFECTIVE FREQUENCY-DEPENDENT LAG ANGLE, MAKING SURE WE KNOW WHICH
            C  QUADRANT IT IS IN
ISN 0204          EPSLNS(LM,LP,LQ)=DATAN(U4)
ISN 0205          IF (U4) 32,38,33
ISN 0206     38   CONTINUE
ISN 0207          IF (U1) 41,37,37
ISN 0208     41   EPSLNS(LM,LP,LQ)=PI
ISN 0209          GO TO 37
ISN 0210     32   CONTINUE
ISN 0211          IF (U2) 35,34,34
ISN 0212     34   EPSLNS(LM,LP,LQ)=EPSLNS(LM,LP,LQ) + PI
ISN 0213     35   CONTINUE
ISN 0214          GO TO 37
ISN 0215     33   CONTINUE
ISN 0216          IF (U2) 36,37,37
ISN 0217     36   EPSLNS(LM,LP,LQ)=EPSLNS(LM,LP,LQ) + PI
ISN 0218     37   CONTINUE
            C  EP IS THE EFFECTIVE TIDAL LAG ANGLE IN DEGREES
ISN 0219          EP=EPSLNS(LM,LP,LQ)/F
ISN 0220          SIGSQR=((E1**2)*(U1**2) + (E2**2)*(U2**2))/U3
            C  SIGLOV IS THE STD. ERROR OF YKS(LM,LP,LQ)
ISN 0221          SIGLOV=DSQRT(SIGSQR)
ISN 0222          SIGSQR=((E2**2)*(U1**2) + (E1**2)*(U2**2))/(U3**2)
            C  SIGLAG IS THE STD. ERROR OF EPSLNS(LM,LP,LQ) IN DEGREES
ISN 0223          SIGLAG=DSQRT(SIGSQR)/F
            C
            C  DO THE OCEAN TIDES
            C
ISN 0224          YM=LM
            C YM*XLAG IS THE LAG ANGLE OF THE SOLID EARTH CONVERTED TO FREQUENCY-DEPENDENT
            C FORM
ISN 0225          CXLAG=DCOS(YM*XLAG)
ISN 0226          SXLAG=DSIN(YM*XLAG)
            C  SUBTRACT OUT THE SOLID EARTH TIDE
ISN 0227          SEA1=U1 - XK*CXLAG
ISN 0228          SEA2=U2 - XK*SXLAG
ISN 0229          SEA3=SEA1**2 + SEA2**2
ISN 0230          SEA5=DSQRT(SEA3)
            C  FIND COCEAN, THE OCEAN AMPLITUDE
ISN 0231          COCEAN=(146.7795D0)*SEA5*B1(LM)*B(LM,LP)/(1.0D0 + XKP)
ISN 0232          SIGSQR=((E1**2)*(SEA1**2) + (E2**2)*(SEA2**2))/SEA3
ISN 0233          SIG=DSQRT(SIGSQR)
            C  SIGC IS THE STD. ERROR OF COCEAN
ISN 0234          SIGC=(146.7795D0)*SIG*B1(LM)*DABS(B(LM,LP))/(1.0D0 + XKP)
ISN 0235          SIGSQR=((E2**2)*(SEA1**2) + (E1**2)*(SEA2**2))/(SEA3**2)
            C  SIGPHS IS THE STD. ERROR OF THE PHASE ANGLE IN DEGREES
ISN 0236          SIGPHS=DSQRT(SIGSQR)/F
ISN 0237          U44=SEA2/SEA1
            C  FIND THE PHASE ANGLE OF THE OCEAN TIDE, MAKING SURE WE KNOW WHICH QUADRANT
            C  IT IS IN
ISN 0238          PHASE=DATAN(U44)
ISN 0239          IF (U44) 52,55,53
ISN 0240     53   CONTINUE
ISN 0241          IF (SEA1) 59,57,57
```

```
ISN 0242      59   PHASE=PI
ISN 0243           GO TO 57
ISN 0244      52   CONTINUE
ISN 0245           IF (SEA2) 55,54,54
ISN 0246      54   PHASE=PHASE + PI
ISN 0247      55   CONTINUE
ISN 0248           GO TO 57
ISN 0249      53   CONTINUE
ISN 0250           IF (SEA2) 56,57,57
ISN 0251      56   PHASE=PHASE + PI
ISN 0252      57   CONTINUE
ISN 0253           PHASE=-PHASE + (YM - 1.0D0)*(PI/2.0D0)
              C  INSURE THAT COCEAN IS A POSITIVE AMPLITUDE
ISN 0254           IF (COCEAN) 73,74,74
ISN 0255      73   COCEAN=-COCEAN
ISN 0256           PHASE=PHASE - PI
ISN 0257      74   CONTINUE
              C  CONVERT PHASE FROM RADIANS TO DEGREES
ISN 0258           PHASE=PHASE/F
ISN 0259           IF (PHASE) 75,76,76
ISN 0260      75   PHASE=PHASE+360.0
ISN 0261      76   CONTINUE
ISN 0262           IF (PHASE) 77,78,78
ISN 0263      77   PHASE=PHASE+360.0
ISN 0264      78   CONTINUE
              C  PRINT OUT L,M,P,Q, CONSTITUENT, DISTURBING BODY, FREQUENCY DEPENDENT LOVE
              C  NUMBER AND ITS ERROR, LAG ANGLE AND ITS ERROR, OCEAN AMPLITUDE AND ITS
              C  ERROR, PHASE ANGLE AND ITS ERROR
ISN 0265           WRITE (6,71) LLL,LM,LPP,LQQ,TIDE(LM,LP,LQ),YKS(LM,LP,LQ),SIGLOV,EP
                  1,SIGLAG,COCEAN,SIGC,PHASE,SIGPHS
ISN 0266      71   FORMAT (4I2,2X,A4,5X,'SUN',5X,F10.5,2X,F10.5,2X,F9.5,3X,F9.5,
                  1 4X,F10.5,2X,F10.5,2X,F9.4,2X,F9.4)
ISN 0267           GO TO 65
ISN 0268      66   CONTINUE
              C  SET THE LOVE NUMBER AND LAG ANGLE TO ZERO FOR TIDES NOT SOLVED FOR
ISN 0269           YKS(LM,LP,LQ)=0.0D0
ISN 0270           EPSLNS(LM,LP,LQ)=0.0D0
ISN 0271           WRITE (6,9) LLL,LM,LPP,LQQ,TIDE(LM,LP,LQ)
ISN 0272       9   FORMAT (4I2,2X,A4,5X,'SUN',12X,'...',9X,'...',8X,'...',9X,'...',
                  1 11X,'...',9X,'...',8X,'...',8X,'...')
ISN 0273      65   CONTINUE
ISN 0274           WRITE (6,94) (SAT(J), J=1,14)
ISN 0275      94   FORMAT (///////,20X,13A5,A2)
              C  PRINT OUT L, T(L), AND XINCL(L)
ISN 0276           DO 10 L=1,MT
ISN 0277           TT=T(L)
ISN 0278           CALL ARG(TT)
ISN 0279           SUM=0.0D0
ISN 0280           DO 70 LM=1,2
ISN 0281           YLM=LM
ISN 0282           DO 70 LP=1,3
ISN 0283           YLP=LP - 1
ISN 0284           DO 70 LQ=1,3
ISN 0285           XMOON(LM,LP,LQ)=YKM(LM,LP,LQ)*CENTM*BI(LM)*C(LM,2)*A1(LM,LP)*GLPQM
                  1(LP,LQ)*YLM*ARGUM(LM,LP,LQ)/(ARGDTM(LM,LP,LQ)*SS)
ISN 0286           XSUN(LM,LP,LQ)=YKS(LM,LP,LQ)*CENTS*BI(LM)*C(LM,2)*E(LM,LP)*GLPQS(L
                  1P,LQ)*YLM*ARGUS(LM,LP,LQ)/(ARGDTS(LM,LP,LQ)*SS)
ISN 0287           SUM=SUM + XMOON(LM,LP,LQ) + XSUN(LM,LP,LQ)
ISN 0288      70   CONTINUE
ISN 0289           XINCL(L)=SUM + XI0
ISN 0290      10   CONTINUE
ISN 0291           WRITE (6,19)
ISN 0292           WRITE (6,100)
ISN 0293     100   FORMAT (40X,'TIDAL INCLINATION',//)
ISN 0294           WRITE (6,101)
ISN 0295     101   FORMAT (35X,'TIME',18X,'INCLINATION')
ISN 0296           WRITE (6,102)
ISN 0297     102   FORMAT (30X,'(JAN 1. 0 HRS UT = 1)',12X,'(ARCSEC)',//)
ISN 0298           DO 12 L=1,MT
ISN 0299           WRITE (6,13) L,T(L),XINCL(L)
ISN 0300      12   CONTINUE
ISN 0301      13   FORMAT (20X,I5,5X,D15.5,10X,D15.5)
              C PRINT RESIDUALS
ISN 0302           WRITE (6,19)
ISN 0303           WRITE (6,103)
ISN 0304     103   FORMAT (45X,'RESIDUALS',//)
ISN 0305           WRITE (6,104)
ISN 0306     104   FORMAT (35X,'TIME',18X,'RESIDUAL')
ISN 0307           WRITE (6,102)
ISN 0308           SUMSIG=0.0
```

```
ISN 0309          DO 4 J=1,MEXP
ISN 0310          TT=TEXP(J)
ISN 0311          CALL ARG(TT)
ISN 0312          SUM=0.0
ISN 0313          DO 3 LM=1,2
ISN 0314          YLM=LM
ISN 0315          DO 3 LP=1,3
ISN 0316          YLP=LP - 1
ISN 0317          DO 3 LQ=1,3
ISN 0318          XMCON(LM,LP,LQ)=YKM(LM,LP,LQ)*CENTM*B1(LM)*C(LM,2)*A1(LM,LP)*GLPQM
                 1(LP,LQ)-YLM*ARGUM(LM,LP,LQ)/(ARGCTM(LM,LP,LQ)*SS)
ISN 0319          XSUN(LM,LP,LQ)=YKS(LM,LP,LQ)*CENTS*B1(LM)*C(LM,2)*B(LM,LP)*GLPQS(L
                 1P,LQ)-YLM*ARGUS(LM,LP,LQ)/(ARGDTS(LM,LP,LQ)*SS)
ISN 0320          SUM=SUM + XMCON(LM,LP,LQ) + XSUN(LM,LP,LQ)
ISN 0321    3     CONTINUE
ISN 0322          SUM=SUM + XI0
ISN 0323          RESI=XIEXP(J) - SUM
ISN 0324          SUMSIG=RESI**2 + SUMSIG
ISN 0325          WRITE (6,13) J,TEXP(J),RESI
ISN 0326    4     CONTINUE
ISN 0327          XN=MEXP - 1
ISN 0328          SIGMA=DSQRT(SUMSIG/XN)
ISN 0329          WRITE (6,105) SIGMA
ISN 0330    105   FORMAT (/////,10X,'SIGMA = SQRT((SUM OF SQUARES)/(MEXP-1)) = ',
                 1 F10.5)
            C  PLOT OUT XINCL(L) VS. T(L), RESIDUALS ON COMPUTER PAPER
ISN 0331          CALL PLOTER(MT,MEXP)
ISN 0332          RETURN
ISN 0333          END
```

```
ISN 0002          SUBROUTINE PLOTER(MT,MEXP)
            C
            C
            C     THIS SUBROUTINE PLOTS A CONTINUOUS CURVE PLUS EXPERIMENTAL DATA POINTS
            C VS. TIME T(L). IT ALSO PLOTS THE RESIDUALS VS. TIME T(L).
            C TIME INCREASES DOWN THE PAGE AND THE WIDTH OF THE PLOT IS 101 SPACES ACROSS.
            C THERE ARE MT POINTS IN THE CURVE, WHICH IS STORED IN ARRAY XINCL(L), AND
            C MEXP EXPERIMENTAL DATA POINTS, STORED IN ARRAY XIEXP(J). THE POINTS OF THE
            C CURVE ARE PRINTED AS D'S AND THE DATA POINTS AS X'S.
            C
            C
ISN 0003          IMPLICIT REAL*8(A-H,O-Z)
ISN 0004          DIMENSION RESID(200)
ISN 0005          DIMENSION BINE(101)
ISN 0006          DIMENSION TEXP(200),XIEXP(200),T(700),XINCL(700),NTRACK(700)
ISN 0007          COMMON/BLKC/TEXP,XIEXP,T,XINCL,NTRACK
ISN 0008          DATA DEE,EKS,BLANK/1HD,1HX,1H /
            C DETERMINE THE WIDTH OF THE PLOT, BY FINDING THE MAXIMUM AND MINIMUM POINTS OF
            C THE CURVE AND THE DATA POINTS
ISN 0009          XMAX1=XINCL(1)
ISN 0010          XMIN1=XINCL(1)
ISN 0011          DO 30 I=2,MT
ISN 0012          P=XINCL(I)
ISN 0013          IF (XMAX1 - P) 22,21,21
ISN 0014     22   XMAX1=P
ISN 0015          GO TO 30
ISN 0016     21   CONTINUE
ISN 0017          IF (P - XMIN1) 24,30,30
ISN 0018     24   XMIN1=P
ISN 0019     30   CONTINUE
ISN 0020          IF (MEXP .EQ. 0) GO TO 4
ISN 0022          GO TO 5
ISN 0023     4    XMAX=XMAX1
ISN 0024          XMIN=XMIN1
ISN 0025          GO TO 50
ISN 0026     5    CONTINUE
ISN 0027          XMAX2=XIEXP(1)
ISN 0028          XMIN2=XIEXP(1)
ISN 0029          DO 40 J=2,MEXP
ISN 0030          P=XIEXP(J)
ISN 0031          IF (XMAX2 - P) 42,41,41
ISN 0032     42   XMAX2=P
ISN 0033          GO TO 40
ISN 0034     41   CONTINUE
ISN 0035          IF (P - XMIN2) 44,40,40
ISN 0036     44   XMIN2=P
ISN 0037     40   CONTINUE
ISN 0038          IF (XMAX2 - XMAX1) 45,46,46
ISN 0039     46   XMAX=XMAX2
ISN 0040          GO TO 47
ISN 0041     45   XMAX=XMAX1
ISN 0042     47   CONTINUE
ISN 0043          IF (XMIN2 - XMIN1) 48,49,49
ISN 0044     48   XMIN=XMIN2
ISN 0045          GO TO 50
ISN 0046     49   XMIN=XMIN1
ISN 0047     50   CONTINUE
            C COMPUTE FAC, SO THAT ALL OF THE POINTS FIT ON THE PAPER
ISN 0048          FAC=100.000/(XMAX-XMIN)
ISN 0049          WRITE (6,3)
ISN 0050     3    FORMAT (1H1)
ISN 0051          SCALE=XMAX - XMIN
            C WRITE THE LOWEST POINT, HIGHEST POINT, AND DISTANCE BETWEEN THEM
ISN 0052          WRITE (6,131) XMIN,XMAX,SCALE
            C SET ARRAY BINE(J) INITIALLY EQUAL TO BLANK
ISN 0053          DO 26 J=1,101
ISN 0054     26   BINE(J)=BLANK
ISN 0055          DO 29 L=1,MT
ISN 0056          J4=1
            C PUT CURVE POINT IN BINE(JJ)
ISN 0057          JJ=(XINCL(L) - XMIN)*FAC + 1.51
ISN 0058          BINE(JJ)=DEE
            C SEE IF AN EXPERIMENTAL DATA POINT SHOULD BE PLOTTED, BY CHECKING THE VALUE OF
            C NTRACK(L)
ISN 0059          IF (NTRACK(L) .EQ. 0) GO TO 50
ISN 0061          NN=NTRACK(L)
            C PUT EXPERIMENTAL DATA POINT IN BINE(J4)
ISN 0062          J4=(XIEXP(NN) - XMIN)*FAC + 1.51
```

```
ISN 0063              BINE(J4)=EKS
ISN 0064       60     CONTINUE
             C PRINT THE NUMBER OF THE CURVE POINT, BINE, AND THE NUMBER OF THE CURVE POINT
ISN 0065              WRITE (6,25) L,(BINE(J1), J1=1,101),L
ISN 0066       25     FORMAT (3X,I5,2X,101A1,1X,I5)
             C PUT ARRAY BINE(J) BACK TO BLANK
ISN 0067              BINE(JJ)=BLANK
ISN 0068              BINE(J4)=BLANK
ISN 0069       29     CONTINUE
ISN 0070              IF (MEXP .EQ. 0) GO TO 130
             C PLOT RESIDUALS VS. TIME
ISN 0072              DO 132 J=1,MEXP
ISN 0073              RESID(J)=0.0
ISN 0074      132     CONTINUE
ISN 0075              DO 101 L=1,MT
ISN 0076              IF (NTRACK(L) .EQ. 0) GO TO 101
ISN 0078              NN=NTRACK(L)
ISN 0079              RESID(NN)=XIEXP(NN) - XINCL(L)
ISN 0080      101     CONTINUE
ISN 0081              XMAX2=RESID(1)
ISN 0082              XMIN2=RESID(1)
ISN 0083              DO 140 J=2,MEXP
ISN 0084              P=RESID(J)
ISN 0085              IF (XMAX2 - P) 142,141,141
ISN 0086      142     XMAX2=P
ISN 0087              GO TO 140
ISN 0088      141     CONTINUE
ISN 0089              IF (P - XMIN2) 144,140,140
ISN 0090      144     XMIN2=P
ISN 0091      140     CONTINUE
ISN 0092              SCALE=XMAX2 - XMIN2
ISN 0093              WRITE (6,3)
ISN 0094              WRITE (6,131) XMIN2,XMAX2,SCALE
ISN 0095      131     FORMAT (/////,10X,'MINIMUM=',F10.5,10X,'MAXIMUM=',F10.5,10X,
                    1 'SCALE=',F10.5,///////)
ISN 0096              FAC=100.0D0/(XMAX2 - XMIN2)
ISN 0097              DO 126 J=1,101
ISN 0098      126     BINE(J)=BLANK
ISN 0099              DO 129 L=1,MT
ISN 0100              J4=1
ISN 0101              JJ=(-XMIN2)*FAC + 1.51
ISN 0102              BINE(JJ)=DEE
ISN 0103              IF (NTRACK(L) .EQ. 0) GO TO 160
ISN 0105              NN=NTRACK(L)
ISN 0106              J4=(RESID(NN) - XMIN2)*FAC + 1.51
ISN 0107              BINE(J4)=EKS
ISN 0108      160     CONTINUE
ISN 0109              WRITE (6,25) L,(BINE(J1), J1=1,101),L
ISN 0110              BINE(JJ)=BLANK
ISN 0111              BINE(J4)=BLANK
ISN 0112      129     CONTINUE
ISN 0113      130     CONTINUE
ISN 0114              RETURN
ISN 0115              END


ISN 0002              SUBROUTINE RDSAT
             C
             C
             C        THIS SUBROUTINE READS IN AND PRINTS OUT THE SATELLITE ELEMENTS AND NODE
             C RATE. ALL INPUT IN DEGREES (OR DEGREES PER DAY) IS IMMEDIATELY CONVERTED TO
             C RADIANS (OR RADIANS PER DAY) FOR USE IN THE PROGRAM.
             C
             C
ISN 0003              IMPLICIT REAL*8(A-H,O-Z)
ISN 0004              DIMENSION SAT(14)
ISN 0005              COMMON/BLKD/XLAG,Q,OMEGAM,DELMN,OMEGAS,DELSUN,SS,XI0,A,E,XI,XNODE,
                    1 TZERO,XIMOON,XISUN,TMS,XNDM,XNDS,F,XMEANM,XMEANS,XMDOTM,XMDOTS,
                    2 OMGDOT,MEXP
ISN 0006              COMMON/BLKI/SAT
ISN 0007              READ (5,7) (SAT(J), J=1,14)
ISN 0008        7     FORMAT (13A6,A2)
ISN 0009              WRITE (6,2)
ISN 0010        2     FORMAT (1H1)
ISN 0011              WRITE (6,8) (SAT(J), J=1,14)
ISN 0012        8     FORMAT (/////,10X,'SATELLITE',1X,13A6,A2)
ISN 0013              READ (5,1) A,E,Q1,XI1,TZERO,XNODE1
ISN 0014        1     FORMAT (3F10.5)
ISN 0015              XI=XI1*F
ISN 0016              Q=Q1*F
ISN 0017              XNODE=XNODE1*F
ISN 0018              WRITE (6,3)
ISN 0019        3     FORMAT (//////,50X,'SATELLITE DATA',/////)
ISN 0020              WRITE (6,4)
ISN 0021        4     FORMAT (24X,'A',14X,'E',10X,'INCLINATION',8X,'NODE RATE',8X,'TZERO
                    1',11X,'NODE',/)
ISN 0022              WRITE (6,5)
ISN 0023        5     FORMAT (20X,'(10**6 CM)',21X,'(DEGREES)',5X,'(DEG/DAY)',8X,'(DAYS)
                    1',8X,'(DEGREES)',//)
ISN 0024              WRITE (6,6) A,E,XI1,Q1,TZERO,XNODE1
ISN 0025        6     FORMAT (20X,6(F10.4,5X))
ISN 0026              RETURN
ISN 0027              END
```

```
ISN 0002          SUBROUTINE READMS
             C
             C
             C    THIS SUBROUTINE READS IN AND PRINTS OUT THE POSITION AND ANGULAR SPEEDS OF
             C THE MOON AND SUN. INPUT IN DEGREES (OR DEGREES PER DAY) IS IMMEDIATELY
             C CONVERTED TO RADIANS (OR RADIANS PER DAY) FOR USE IN THE PROGRAM.
             C
             C
ISN 0003          IMPLICIT REAL*8(A-H,O-Z)
ISN 0004          COMMON/BLKD/ XLAG,Q,OMEGAM,DELMN,OMEGAS,DELSUN,SS,XIO,A,E,XI,XNODE,
                 1 TZERO,XIMOON,XISUN,TMS,XNDM,XNDS,F,XMEANM,XMEANS,XMDOTM,XMDOTS,
                 2 OMGDOT,MEXP
ISN 0005          READ (5,1) OMEGA1,DELTA1,OMEGA2,DELTA2,XNDM1,OMGDT1
ISN 0006          READ (5,1) XID1,XID2,TMS,XMEAN1,XMEAN2
ISN 0007      1   FORMAT (3F10.5)
ISN 0008          XIMOON=XID1*F
ISN 0009          XISUN=XID2*F
ISN 0010          DELMN=DELTA1*F
ISN 0011          DELSUN=DELTA2*F
ISN 0012          OMEGAM=OMEGA1*F
ISN 0013          OMEGAS=OMEGA2*F
ISN 0014          XMEANM=XMEAN1*F
ISN 0015          XMEANS=XMEAN2*F
ISN 0016          XNDM=XNDM1*F
ISN 0017          OMGDOT=OMGDT1*F
ISN 0018          XNDS1=0.985647
ISN 0019          WRITE (6,2)
ISN 0020      2   FORMAT (10X,/////,53X,'MOON AND SUN DATA',/////)
ISN 0021          WRITE (6,3)
ISN 0022      3   FORMAT (23X,'OMEGA',10X,'DELTA',7X,'INCLINATION',7X,' TMS ',8X,
                 1 'MEAN ANOMALY',2X,'MEAN MOTION',5X,'NODE RATE',/)
ISN 0023          WRITE (6,4)
ISN 0024      4   FORMAT (21X,'(DEGREES)',6X,'(DEGREES)',6X,'(DEGREES)',7X,'(DAYS)',
                 1 9X,'(DEGREES)',4X,'(DEG/DAY)',6X,'(DEG/DAY)',//)
ISN 0025          WRITE (6,5) OMEGA1,DELTA1,XID1,TMS,XMEAN1,XNDM1,OMGDT1
ISN 0026      5   FORMAT (6X,'MOON',10X,7(F10.4,5X),/)
ISN 0027          WRITE (6,6) OMEGA2,DELTA2,XID2,TMS,XMEAN2,XNDS1
ISN 0028      6   FORMAT (6X,'SUN',11X,6(F10.4,5X))
ISN 0029          RETURN
ISN 0030          END
```

ORIGINAL PAGE IS
OF POOR QUALITY

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ISN 0002          SUBROUTINE REGRES(MT)
                C
                C
                C     THIS SUBROUTINE CARRIES OUT THE MULTIPLE REGRESSION ANALYSIS.
                C     THIS SUBROUTINE IS A MODIFICATION OF THE PROGRAM EXPLAINED AND LISTED ON
                C PAGES 404 - 407 OF THE IBM SYSTEM/360 SCIENTIFIC SUBROUTINE PACKAGE,
                C VERSION III, PROGRAMMERS MANUAL, PROGRAM NUMBER 360A-CM-03X, FIFTH EDITION
                C (AUGUST 1970).
                C     THE PURPOSE HERE IS TO (1) READ THE PROBLEM PARAMETER CARD FOR A MULTIPLE
                C REGRESSION, (2) READ SUBSET SELECTION CARDS, (3) CALL THE SUBROUTINES TO
                C CALCULATE MEANS, STANDARD DEVIATIONS, SIMPLE AND MULTIPLE CORRELATION
                C COEFFICIENTS, T-VALUES, AND ANALYSIS OF VARIANCE FOR MULTIPLE REGRESSION,
                C (4) PRINT THE RESULTS, AND (5) SAVE THE REGRESSION COEFFICIENTS AND THEIR
                C ERRORS FOR SUBROUTINE LOVNUM.
                C     THE NUMBER OF OBSERVATIONS, MEXP, IS CALLED N IN THIS SUBROUTINE. N MUST
                C BE GREATER THAN M+1, WHERE M IS THE NUMBER OF VARIABLES.
                C     IF SUBSET SELECTION CARDS ARE NOT PRESENT, THE PROGRAM CANNOT PERFORM
                C MULTIPLE REGRESSION.
                C     AFTER RETURNING FROM SUBROUTINE MINV, THE VALUE OF DETERMINANT (DET) IS
                C TESTED TO CHECK WHETHER THE CORRELATION MATRIX IS SINGULAR. IF DET IS
                C COMPARED AGAINST A SMALL CONSTANT, THIS TEST MAY ALSO BE USED TO CHECK NEAR-
                C SINGULARITY.
                C     THIS SUBROUTINE CALLS SUBROUTINES CORRE (WHICH, IN TURN, CALLS SUBROUTINE
                C DATA), ORDER, MINV, MULTR. ONLY DATA IS FOUND LISTED HERE, SINCE THE OTHERS
                C ARE STANDARD SUBROUTINES CONTAINED IN THE MACHINE.
                C
                C
                C     THE SUBSET SELECTION CARD(S) GIVES K, THE NUMBER OF COEFFICIENTS SOLVED
                C FOR, AND (ISAVE(J), J=1,K), WHICH CONTAINS THE TIDAL CONSTITUENTS SOLVED FOR.
                C THE TABLE BELOW GIVES THE TIDAL CONSTITUENTS AND THEIR ISAVE(J) VALUES.
                C
                C
                C     L M P Q   TIDE   DIS.BODY    ISAVE(J) VALUES
                C
                C     2 1 0-1            MOON        1 AND  2
                C     2 1 0 0   O1       MOON        3 AND  4
                C     2 1 0 1            MOON        5 AND  6
                C     2 1 1-1            MOON        7 AND  8
                C     2 1 1 0   K1     MOON+SUN      9 AND 10
                C     2 1 1 1            MOON       11 AND 12
                C     2 1 2-1            MOON       13 AND 14
                C     2 1 2 0            MOON       15 AND 16
                C     2 1 2 1            MOON       17 AND 18
                C     2 2 0-1            MOON       19 AND 20
                C     2 2 0 0   M2       MOON       21 AND 22
                C     2 2 0 1            MOON       23 AND 24
                C     2 2 1-1            MOON       25 AND 26
                C     2 2 1 0   K2     MOON+SUN     27 AND 28
                C     2 2 1 1            MOON       29 AND 30
                C     2 2 2-1            MOON       31 AND 32
                C     2 2 2 0            MOON       33 AND 34
                C     2 2 2 1            MOON       35 AND 36
                C
                C     2 1 0-1             SUN       37 AND 38
                C     2 1 0 0   P1        SUN       39 AND 40
                C     2 1 0 1             SUN       41 AND 42
                C     2 1 1-1             SUN       43 AND 44
                C     2 1 1 0   K1S       SUN          -
                C     2 1 1 1             SUN       45 AND 46
                C     2 1 2-1             SUN       47 AND 48
                C     2 1 2 0             SUN       49 AND 50
                C     2 1 2 1             SUN       51 AND 52
                C     2 2 0-1             SUN       53 AND 54
                C     2 2 0 0   S2        SUN       55 AND 56
                C     2 2 0 1             SUN       57 AND 58
                C     2 2 1-1             SUN       59 AND 60
                C     2 2 1 0   K2S       SUN          -
                C     2 2 1 1             SUN       61 AND 62
                C     2 2 2-1             SUN       63 AND 64
                C     2 2 2 0             SUN       65 AND 66
                C     2 2 2 1             SUN       67 AND 68
                C
                C
                C     EACH CONSTITUENT HAS TWO ISAVE(J) VALUES, SINCE WE SOLVE FOR TWO
                C PARAMETERS  A LOVE NUMBER AND A LAG ANGLE. IF WE WISH TO SOLVE FOR ONLY A
                C LOVE NUMBER (FORCING THE LAG ANGLE TO BE ZERO), THEN ONLY THE FIRST ISAVE(J)
                C VALUE OF THAT CONSTITUENT SHOULD APPEAR ON THE SUBSET SELECTION CARD.
                C
```

```
                C
                C
                C THE FOLLOWING DIMENSIONS MUST BE GREATER THAN OR EQUAL TO THE NUMBER OF
                C VARIABLES, M
                C
                C
ISN 0003              DIMENSION XBAR(70),STD(70),D(70),RY(70),ISAVE(70),V(70),
                     1 SB(70),T(70),W(70)
                C THE FOLLOWING DIMENSION MUST BE GREATER THAN OR EQUAL TO THE PRODUCT OF M*M
ISN 0004              DIMENSION RX(4900)
                C THE FOLLOWING DIMENSION MUST BE GREATER THAN OR EQUAL TO (M+1)*M/2
ISN 0005              DIMENSION R(2500)
                C THE FOLLOWING DIMENSION MUST BE GREATER THAN OR EQUAL TO 10
ISN 0006              DIMENSION ANS(10)
ISN 0007              DIMENSION VV(70),VE(70)
ISN 0008              COMMON/BLKG/C,A1,B,GLPQM,GLPQS,INDEX
ISN 0009              COMMON/BLKH/VV,VE,ANS,ISAVE,M,K
ISN 0010          1   FORMAT (A4,A2,I5,2I2)
ISN 0011          2   FORMAT (1H1,'MULTIPLE REGRESSION',5X,A4,A2//6X,'SELECTION',I2,//)
ISN 0012          3   FORMAT (1H0,'VARIABLE',5X,'MEAN',6X,'STANDARD',6X,'CORRELATION',
                     1 4X,'REGRESSION',4X,'STD. ERROR',5X,'COMPUTED',/,'   NO.',18X,
                     2'DEVIATION',7X,'X VS. Y',7X,'COEFFICIENT',3X,'OF REG.COEF.',3X,'T
                     3VALUE')
ISN 0013          4   FORMAT (1H ,I4,6F14.5)
ISN 0014          5   FORMAT (1H ,'DEPENDENT')
ISN 0015          6   FORMAT (1H0,/,1H ,'INTERCEPT',10X,F16.5,//,1H ,'MULTIPLE CORRELATI
                     1ON',F15.5,//,1H ,'STD. ERROR OF ESTIMATE',F13.5,//)
ISN 0016          7   FORMAT (1H0,21X,'ANALYSIS OF VARIANCE FOR THE REGRESSION',//,5X,
                     1 'SOURCE OF VARIATION',7X,'DEGREES',7X,'SUM OF',10X,'MEAN',12X,
                     2 'F VALUE',/,30X,'OF FREEDOM',4X,'SQUARES',9X,'SQUARES')
ISN 0017          8   FORMAT (1H ,'ATTRIBUTABLE TO REGRESSION',4X,I5,3F16.5,/,1H ,
                     1 'DEVIATION FROM REGRESSION',4X,I6,2F16.5)
ISN 0018          9   FORMAT (1H ,5X,'TOTAL',19X,I6,F16.5)
ISN 0019         10   FORMAT (36I2)
ISN 0020         11   FORMAT (1H ,15X,'TABLE OF RESIDUALS',//,1H ,'CASE NO.',5X,'Y VALUE
                     1',5X,'Y ESTIMATE',6X,'RESIDUAL')
ISN 0021         12   FORMAT (1H ,I6,F15.5,2F14.5)
ISN 0022         13   FORMAT (1H1,'NUMBER OF SELECTIONS NOT SPECIFIED. JOB TERMINATED')
ISN 0023         14   FORMAT (1H0,'THE MATRIX IS SINGULAR. THIS SELECTION IS SKIPPED.')
ISN 0024         15   FORMAT (10X,7F10.3)
                C READ THE PROBLEM PARAMETER CARD
                C
                C PR,PR1 - ALPHANUMERIC NAME OF SATELLITE
                C      N - NUMBER OF OBSERVATIONS
                C      M - NUMBER OF VARIABLES
                C     NS - NUMBER OF SELECTIONS
                C
ISN 0025        100   READ (5,1,END=300)PR,PR1,N,M,NS
ISN 0026              IO=0
ISN 0027              X=0.0
ISN 0028              MV= M - 1
ISN 0029              DO 30 JA=1,MV
ISN 0030         30   VV(JA)=0.0
ISN 0031              CALL CORRE (N,M,IO,X,XBAR,STD,RX,R,D,V,T)
                C TEST NUMBER OF SELECTIONS
ISN 0032              IF (NS) 108,108,109
ISN 0033        108   WRITE (6,13)
ISN 0034              GO TO 300
ISN 0035        109   DO 200 I=1,NS
ISN 0036              WRITE (6,2) PR,PR1,I
                C READ SUBSET SELECTION CARD
                C
                C      K - NUMBER OF INDEPENDENT VARIABLES INCLUDED
                C  ISAVE - A VECTOR CONTAINING THE INDEPENDENT VARIABLES INCLUDED
                C
ISN 0037              READ (5,10) K,(ISAVE(J), J=1,K)
                C   NDEP - DEPENDENT VARIABLE
ISN 0038              NDEP=69
ISN 0039              CALL ORDER(M,R,NDEP,K,ISAVE,RX,RY)
ISN 0040              CALL MINV (RX,K,DET,V,T)
                C TEST SINGULARITY OF THE MATRIX INVERTED
ISN 0041              IF (DET) 112,110,112
ISN 0042        110   WRITE (6,14)
ISN 0043              GO TO 200
ISN 0044        112   CALL MULTR (N,K,XBAR,STD,D,RX,RY,ISAVE,V,SB,T,ANS)
                C PRINT MEANS, STANDARD DEVIATIONS, INTERCORRELATIONS BETWEEN X AND Y,
                C REGRESSION COEFFICIENTS, STANDARD DEVIATIONS OF REGRESSION COEFFICIENTS, AND
                C COMPUTED T-VALUES
ISN 0045              MM=K + 1
ISN 0046              WRITE (6,3)
```

```
ISN 0047          DO 115 J=1,K
ISN 0048          L=ISAVE(J)
            C SAVE REGRESSION COEFFICIENTS AND THEIR ERRORS FOR SUBROUTINE LOVNUM
ISN 0049          VV(L)=V(J)
ISN 0050          VE(L)=SB(J)
ISN 0051     115  WRITE (6,4) L,XBAR(L),STD(L),RY(J),V(J),SB(J),T(J)
ISN 0052          WRITE (6,5)
ISN 0053          L=ISAVE(MM)
ISN 0054          WRITE (6,4) L,XBAR(L),STD(L)
            C PRINT INTERCEPT, MULTIPLE CORRELATION COEFFICIENT, AND STANDARD ERROR OF
            C ESTIMATE
ISN 0055          WRITE (6,6) ANS(1),ANS(2),ANS(3)
            C PRINT ANALYSIS OF VARIANCE FOR THE REGRESSION
ISN 0056          WRITE (6,7)
ISN 0057          L=ANS(8)
ISN 0058          WRITE (6,8) K,ANS(4),ANS(6),ANS(10),L,ANS(7),ANS(9)
ISN 0059          L=N - 1
ISN 0060          SUM=ANS(4) + ANS(7)
ISN 0061          WRITE (6,9) L,SUM
            C CALL SUBROUTINE LOVNUM
ISN 0062          CALL LOVNUM(MT)
ISN 0063     200  CONTINUE
ISN 0064          GO TO 100
ISN 0065     300  CONTINUE
ISN 0066          RETURN
ISN 0067          END
```

```
ISN 0002          SUBROUTINE THEORY (JPLOT,MT)
            C
            C
            C     THIS SUBROUTINE COMPUTES THE PERIODS AND AMPLITUDES OF THE CONSTITUENT
            C TIDES OF THE TIP FOR THE SOLID EARTH, GIVEN THE SOLID EARTH LOVE NUMBERS. THE
            C LAG ANGLE IS ASSUMED TO BE ZERO HERE. IT ALSO PLOTS THE RESULTING TIP AS A
            C SAMPLE PLOT IF DESIRED (JPLOT=1 IF YES, 0 IF NO).
            C     NOTE  LUNISOLAR TIDES K1 AND K2 ARE LUMPED IN WITH THE LUNAR TIDES.
            C
            C
            C
            C     NOTATION
            C PERDM(LM,LP,LQ)   -   PERIOD OF LUNAR CONSTITUENT LM,LP,LQ
            C PERDS(LM,LP,LQ)   -   PERIOD OF SOLAR CONSTITUENT LM,LP,LQ
            C XMOON(LM,LP,LQ)   -   AMPLITUDE OF LUNAR CONSTITUENT LM,LP,LQ IN ARCSECONDS
            C XSUN(LM,LP,LQ)    -   AMPLITUDE OF SOLAR CONSTITUENT LM,LP,LQ IN ARCSECONDS
            C
            C
ISN 0003          IMPLICIT REAL*8(A-H,O-Z)
ISN 0004          DIMENSION EPSLNM(2,3,3),EPSLNS(2,3,3),ARGUM(2,3,3),ARGUS(2,3,3),
                 1 ARGDTM(2,3,3),ARGDTS(2,3,3)
ISN 0005          DIMENSION   B1(2),XMOON(2,3,3),XSUN(2,3,3),YKM(2,3,3),YKS(2,3,3)
ISN 0006          DIMENSION TEXP(200),XIEXP(200),T(700),XINCL(700),NTRACK(700)
ISN 0007          DIMENSION C(2,3),A1(2,3),B(2,3),GLPQM(3,3),GLPQS(3,3)
ISN 0008          DIMENSION TIDE(2,3,3)
ISN 0009          DIMENSION SAT(14)
ISN 0010          DIMENSION PERDM(2,3,3),PERDS(2,3,3)
ISN 0011          COMMON/BLKA/EPSLNM,EPSLNS,ARGUM,ARGUS,ARGDTM,ARGDTS
ISN 0012          COMMON/BLKB/B1,XK,CENTM,CENTS,SUM,XMOON,XSUN,YKM,YKS,XKP
ISN 0013          COMMON/BLKC/TEXP,XIEXP,T,XINCL,NTRACK
ISN 0014          COMMON/BLKD/XLAG,Q,OMEGAM,DELMN,OMEGAS,DELSUN,SS,XIO,A,E,XI,XNODE,
                 1 TZERO,XIMOON,XISUN,TMS,XNOM,XNDS,F,XMEANM,XMEANS,XMDOTM,XMDOTS,
                 2 OMGDOT,MEXP
ISN 0015          COMMON/BLKG/C,A1,B,GLPQM,GLPQS,INDEX
ISN 0016          COMMON/BLKI/SAT
ISN 0017          DATA BLANK/4H    /
ISN 0018          DATA TM112,TM122,TM212,TM222/4HO1  ,4HK1  ,4HM2  ,4HK2  /
ISN 0019          DATA TS112,TS122,TS212,TS222/4HP1  ,4HK1S ,4HS2  ,4HK2S /
ISN 0020          PI=3.141592653590D0
            C FIND THE LARGEST AMPLITUDE OF ALL THE CONSTITUENTS (IGNORING ANY CONSTITUENT
            C WITH A PERIOD LONGER THAN 2000 DAYS. THE 2000 IS AN ARBITRARY FIGURE.)
ISN 0021          XMAX=0.0
ISN 0022          DO 60 LM=1,2
ISN 0023          YLM=LM
ISN 0024          DO 60 LP=1,3
ISN 0025          DO 60 LQ=1,3
ISN 0026          YKM(LM,LP,LQ)=XK
ISN 0027          YKS(LM,LP,LQ)=XK
ISN 0028          XMOON(LM,LP,LQ)=YKM(LM,LP,LQ)*CENTM*B1(LM)*C(LM,2)*A1(LM,LP)*
                 1 GLPQM(LP,LQ)*YLM/(ARGDTM(LM,LP,LQ)*SS)
ISN 0029          XMOON(LM,LP,LQ)=DABS(XMOON(LM,LP,LQ))
ISN 0030          PERDM(LM,LP,LQ)=2.0*PI/(ARGDTM(LM,LP,LQ))
ISN 0031          PERDM(LM,LP,LQ)=DABS(PERDM(LM,LP,LQ))
ISN 0032          XSUN(LM,LP,LQ)=YKS(LM,LP,LQ)*CENTS*B1(LM)*C(LM,2)*B(LM,LP)*
                 1 GLPQS(LP,LQ)*YLM/(ARGDTS(LM,LP,LQ)*SS)
ISN 0033          XSUN(LM,LP,LQ)=DABS(XSUN(LM,LP,LQ))
            C TAKE CARE OF THE LUNISOLAR CASE
ISN 0034          IF (LP .EQ. 2 .AND. LQ .EQ. 2) XMOON(LM,LP,LQ)=XMOON(LM,LP,LQ) +
                 1 XSUN(LM,LP,LQ)
ISN 0036          PERDS(LM,LP,LQ)=2.0*PI/(ARGDTS(LM,LP,LQ))
ISN 0037          PERDS(LM,LP,LQ)=DABS(PERDS(LM,LP,LQ))
ISN 0038          PER=PERDM(LM,LP,LQ)
ISN 0039          IF (PER-2000.0) 64,64,62
ISN 0040    64    CONTINUE
ISN 0041          IF (XMOON(LM,LP,LQ)-XMAX) 62,62,63
ISN 0042    63    XMAX=XMOON(LM,LP,LQ)
ISN 0043    62    CONTINUE
ISN 0044          PER=PERDS(LM,LP,LQ)
ISN 0045          IF (PER - 2000.0) 65,65,66
ISN 0046    65    CONTINUE
ISN 0047          IF (XSUN(LM,LP,LQ) - XMAX) 66,66,67
ISN 0048    67    XMAX=XSUN(LM,LP,LQ)
ISN 0049    66    CONTINUE
ISN 0050    60    CONTINUE
ISN 0051          WRITE (6,3)
ISN 0052     3    FORMAT (1H1,////)
ISN 0053          WRITE (6,1)
            C DO THE LUNAR TIDES
            C PRINT OUT L,M,P,Q, CONSTITUENT NAME,DISTURBING BODY, AMPLITUDE IN ARCSEC.
```

```
                C PERIOD IN DAYS, PER CENT OF LARGEST CONSTITUENT, AND ISAVE(J) VALUES
ISN 0054          1   FORMAT (' L M P Q   TIDE    DIS.BODY      AMPLITUDE           PERIOD
                    1     PER CENT   ISAVE(J) (FOR USE IN SUBROUTINE REGRES)')
ISN 0055              WRITE (6,2)
ISN 0056          2   FORMAT (32X,'(ARCSEC)',10X,'(DAYS)',/)
ISN 0057              DO 89 LM=1,2
ISN 0058              DO 89 LP=1,3
ISN 0059              DO 89 LQ=1,3
ISN 0060         89   TIDE(LM,LP,LQ)=BLANK
ISN 0061              TIDE(1,1,2)=TM112
ISN 0062              TIDE(1,2,2)=TM122
ISN 0063              TIDE(2,1,2)=TM212
ISN 0064              TIDE(2,2,2)=TM222
ISN 0065              LLL=2
ISN 0066              I=0
ISN 0067              DO 70 LM=1,2
ISN 0068              DO 70 LP=1,3
ISN 0069              LPP=LP - 1
ISN 0070              DO 70 LQ=1,3
ISN 0071              LQQ=LQ - 2
ISN 0072              AMP=(XMOON(LM,LP,LQ)/XMAX)*100.0
ISN 0073              I=I + 1
ISN 0074              I3=I
ISN 0075              I=I+1
ISN 0076              IF (LPP .EQ. 1 .AND. LQQ .EQ. 0) GO TO 71
ISN 0078              WRITE (6,5) LLL,LM,LPP,LQQ,TIDE(LM,LP,LQ),XMOON(LM,LP,LQ),
                    1 PERDM(LM,LP,LQ),AMP,I3,I
ISN 0079          5   FORMAT (4I2,3X,A4,5X,'MOON',5X,D13.6,3X,F10.3,3X,F10.3,4X,I2,
                    1 ' AND ',I2)
ISN 0080              GO TO 70
ISN 0081         71   WRITE (6,6) LLL,LM,LPP,LQQ,TIDE(LM,LP,LQ),XMOON(LM,LP,LQ),
                    1 PERDM(LM,LP,LQ),AMP,I3,I
ISN 0082          6   FORMAT (4I2,3X,A4,3X,'MOON+SUN',3X,D13.6,3X,F10.3,3X,F10.3,4X,I2,
                    1 ' AND ',I2)
ISN 0083         70   CONTINUE
ISN 0084              WRITE (6,4)
ISN 0085          4   FORMAT (10X,//)
                C DO THE SOLAR TIDES
                C PRINT OUT L,M,P,Q, CONSTITUENT NAME,DISTURBING BODY, AMPLITUDE IN ARCSEC,
                C PERIOD IN DAYS, PER CENT OF LARGEST CONSTITUENT, AND ISAVE(J) VALUES
ISN 0086              DO 88 LM=1,2
ISN 0087              DO 88 LP=1,3
ISN 0088              DO 88 LQ=1,3
ISN 0089         88   TIDE(LM,LP,LQ)=BLANK
ISN 0090              TIDE(1,1,2)=TS112
ISN 0091              TIDE(1,2,2)=TS122
ISN 0092              TIDE(2,1,2)=TS212
ISN 0093              TIDE(2,2,2)=TS222
ISN 0094              DO 80 LM=1,2
ISN 0095              DO 80 LP=1,3
ISN 0096              LPP=LP - 1
ISN 0097              DO 80 LQ=1,3
ISN 0098              LQQ=LQ - 2
ISN 0099              AMP=(XSUN(LM,LP,LQ)/XMAX)*100.0
ISN 0100              IF (LPP .EQ. 1 .AND. LQQ .EQ. 0) GO TO 81
ISN 0102              I=I + 1
ISN 0103              I3=I
ISN 0104              I=I + 1
ISN 0105              WRITE (6,7) LLL,LM,LPP,LQQ,TIDE(LM,LP,LQ),XSUN(LM,LP,LQ),
                    1 PERDS(LM,LP,LQ),AMP,I3,I
ISN 0106          7   FORMAT (4I2,3X,A4,5X,'SUN',6X,D13.6,3X,F10.3,3X,F10.3,4X,I2,
                    1 ' AND ',I2)
ISN 0107              GO TO 80
ISN 0108         81   WRITE (6,8) LLL,LM,LPP,LQQ,TIDE(LM,LP,LQ)
ISN 0109          8   FORMAT (4I2,3X,A4,5X,'SUN',10X,'...',14X,'...',11X,'...',5X,'...')
ISN 0110         80   CONTINUE
ISN 0111              WRITE (6,20) XK
ISN 0112         20   FORMAT (/////,10X,'THEORETICAL AMPLITUDES ASSUMING SOLID EARTH LOV
                    1E NUMBER K2 = ',F7.3)
ISN 0113              WRITE (6,21) (SAT(J), J=1,14)
ISN 0114         21   FORMAT (/////,10X,13A6,A2)
                C PRINT OUT A PLOT OF THE SOLID EARTH TIP (IF JPLOT=1)
ISN 0115              IF (JPLOT .EQ. 1) GO TO 83
ISN 0117              GO TO 12
ISN 0118         83   CONTINUE
ISN 0119              DO 10 L=1,MT
ISN 0120              TT=T(L)
ISN 0121              CALL ARG(TT)
ISN 0122              SUM=0.0
ISN 0123              DO 90 LM=1,2
```

```
ISN 0124           YLM=LM
ISN 0125           DO 90 LP=1,3
ISN 0126           DO 90 LQ=1,3
ISN 0127           XMOON(LM,LP,LQ)=YKM(LM,LP,LQ)*CENTM*B1(LM)*C(LM,2)*A1(LM,LP)*GLPQM
                  1(LP,LQ)*YLM*ARGUM(LM,LP,LQ)/(ARGCTM(LM,LP,LQ)*SS)
ISN 0128           XSUN(LM,LP,LQ)=YKS(LM,LP,LQ)*CENTS*B1(LM)*C(LM,2)*E(LM,LP)*GLPQS(L
                  1P,LQ)*YLM*ARGUS(LM,LP,LQ)/(ARGCTS(LM,LP,LQ)*SS)
ISN 0129           SUM=SUM + XMOON(LM,LP,LQ) + XSUN(LM,LP,LQ)
ISN 0130      90   CONTINUE
ISN 0131           XINCL(L)=SUM
ISN 0132      10   CONTINUE
ISN 0133           CALL PLOTER (MT,MEXP)
ISN 0134      12   CONTINUE
ISN 0135           RETURN
ISN 0136           END
```

```
ISN 0002           SUBROUTINE TIME1(TSTART,TEND,DT,M)
              C
              C
              C    THIS SUBROUTINE FILLS IN THE VALUES OF ARRAY T(L), BY KNOWING THE STARTING
              C TIME (TSTART), THE ENDING TIME (TEND), AND THE TIME INTERVAL BETWEEN
              C POINTS (DT).
              C
              C
ISN 0003           IMPLICIT REAL*8 (A-H,O-Z)
ISN 0004           DIMENSION TEXP(200),XIEXP(200),T(700),XINCL(700),NTRACK(700)
ISN 0005           COMMON/BLKC/TEXP,XIEXP,T,XINCL,NTRACK
ISN 0006           M=(TEND-TSTART)/DT + 1.1D0
ISN 0007           DO 12 L=1,M
ISN 0008           XM=L-1
ISN 0009      12   T(L)=TSTART + XM*DT
ISN 0010           RETURN
ISN 0011           END
```

SATELLITE GEOS - 1 , 1966-1967 DATA

SATELLITE DATA

A (10**8 CM)	E	INCLINATION (DEGREES)	NODE RATE (DEG/DAY)	TZERO (DAYS)	NODE (DEGREES)
8.0729	0.0726	59.3805	-2.2465	38.5000	-109.0820

MOON AND SUN DATA

	OMEGA (DEGREES)	DELTA (DEGREES)	INCLINATION (DEGREES)	TMS (DAYS)	MEAN ANOMALY (DEGREES)	MEAN MOTION (DEG/DAY)	NODE RATE (DEG/DAY)
MOON	10.1770	105.9932	27.2082	35.0000	331.5588	13.1839	-0.0082
SUN	0.0	313.7163	23.4432	35.0000	31.3590	0.9856	

TSTART= 37.0000 TEND= 665.0000 DT= 2.0000 (DAYS)

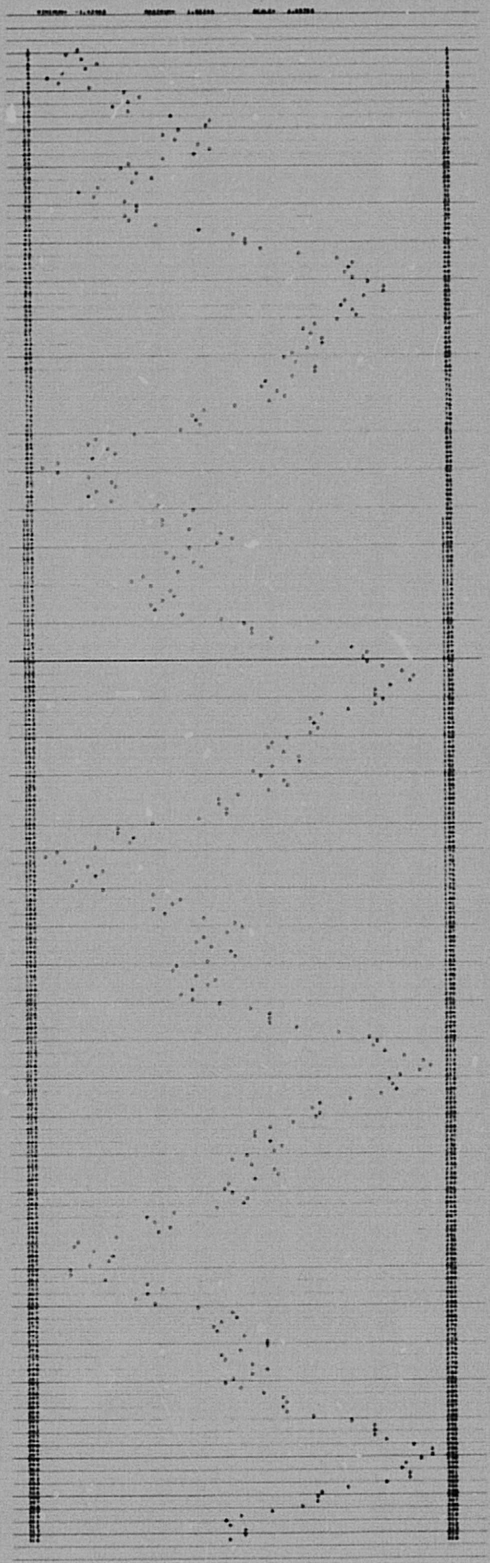
SOLID EARTH LOVE NUMBER= 0.3000 LOAD DEFORMATION COEFFICIENT= -0.3000

SOLID EARTH LAG ANGLE= 0.0 DEGREES

L M P Q	TIDE	DIS.BODY	AMPLITUDE (ARCSEC)	PERIOD (DAYS)	PER CENT	ISAVE(J) (FOR USE IN SUBROUTINE REGRES)
2 1 0-1		MOON	0.272512D-02	23.164	0.298	1 AND 2
2 1 0 0	O1	MOON	0.539345D-01	12.565	5.894	3 AND 4
2 1 0 1		MOON	0.711427D-02	8.639	0.777	5 AND 6
2 1 1-1		MOON	0.110481D-01	33.251	1.207	7 AND 8
2 1 1 0	K1	MOON+SUN	0.915073D 00	160.830	100.000	9 AND 10
2 1 1 1		MOON	0.781613D-02	23.524	0.854	11 AND 12
2 1 2-1		MOON	0.466793D-03	9.679	0.051	13 AND 14
2 1 2 0		MOON	0.374468D-02	14.920	0.409	15 AND 16
2 1 2 1		MOON	0.224170D-03	32.537	0.024	17 AND 18
2 2 0-1		MOON	0.831541D-02	20.248	0.909	19 AND 20
2 2 0 0	M2	MOON	0.174615D 00	11.671	19.082	21 AND 22
2 2 0 1		MOON	0.235691D-01	8.199	2.576	23 AND 24
2 2 1-1		MOON	0.604903D-02	41.918	0.661	25 AND 26
2 2 1 0	K2	MOON+SUN	0.189669D 00	80.415	20.727	27 AND 28
2 2 1 1		MOON	0.296153D-02	20.522	0.324	29 AND 30
2 2 2-1		MOON	0.101543D-03	10.299	0.011	31 AND 32
2 2 2 0		MOON	0.843852D-03	15.445	0.092	33 AND 34
2 2 2 1		MOON	0.574523D-04	40.789	0.006	35 AND 36
2 1 0-1		SUN	0.161423D-02	111.378	0.176	37 AND 38
2 1 0 0	P1	SUN	0.148147D 00	85.352	16.190	39 AND 40
2 1 0 1		SUN	0.701901D-02	69.185	0.767	41 AND 42
2 1 1-1		SUN	0.113792D-01	285.502	1.298	43 AND 44
2 1 1 0	K1S	SUN	...	...	...	...
2 1 1 1		SUN	0.463435D-02	111.381	0.506	45 AND 46
2 1 2-1		SUN	0.221337D-02	506.786	0.242	47 AND 48
2 1 2 0		SUN	0.977311D-01	1307.942	10.680	49 AND 50
2 1 2 1		SUN	0.178145D-03	285.524	0.019	51 AND 52
2 2 0-1		SUN	0.387753D-02	55.708	0.424	53 AND 54
2 2 0 0	S2	SUN	0.393573D 00	55.690	43.010	55 AND 56
2 2 0 1		SUN	0.199610D-01	48.322	2.181	57 AND 58
2 2 1-1		SUN	0.156445D-02	102.638	0.171	59 AND 60
2 2 1 0	K2S	SUN	...	...	...	...
2 2 1 1		SUN	0.100157D-02	65.709	0.109	61 AND 62
2 2 2-1		SUN	0.179401D-03	234.348	0.020	63 AND 64
2 2 2 0		SUN	0.186973D-02	142.756	0.204	65 AND 66
2 2 2 1		SUN	0.112250D-04	102.641	0.001	67 AND 68

THEORETICAL AMPLITUDES ASSUMING SOLID EARTH LOVE NUMBER K2 = 0.300

GEOS - 1 . 1966-1967 DATA



SATELLITE TRACKING DATA

(142 DATA POINTS, TDAY= 38.5000 DAYS)

	TIME (DAYS) (JAN 1, 0 HRS UT = 1)	INCLINATION (ARCSEC)
1	38.5000	-1.1394
2	51.5000	-0.8971
3	58.5000	-0.5935
4	62.5000	-0.6999
5	64.5000	-0.2256
6	66.5000	0.0125
7	68.5000	-0.1465
8	70.5000	-0.3124
9	86.5000	-0.7062
10	90.5000	-0.6178
11	94.5000	-0.7388
12	98.5000	-0.8415
13	102.5000	-0.6733
14	106.5000	-0.6061
15	110.5000	-0.4471
16	114.5000	0.1713
17	118.5000	0.3472
18	122.5000	0.5879
19	126.5000	0.8688
20	130.5000	0.9427
21	134.5000	1.0141
22	139.5000	0.9800
23	143.5000	0.7383
24	147.5000	0.7650
25	151.5000	0.6338
26	155.5000	0.3569
27	159.5000	0.6396
28	163.3750	0.3583
29	168.5000	0.4175
30	172.5000	0.6493
31	176.5000	0.4152
32	180.5000	0.3485
33	184.5000	0.2236
34	188.5000	-0.1095
35	192.5000	-0.1428
36	196.5000	-0.3616
37	200.5000	-0.7914
38	204.5000	-0.8355
39	207.5000	-0.8165
40	211.5000	-0.9939
41	214.5000	-1.1035
42	218.5000	-0.7276
43	222.5000	-0.7276
44	226.5000	-0.6962
45	230.5000	-0.3618
46	250.5000	-0.2757
47	270.5000	-0.6275
48	273.5000	-0.6399
49	277.5000	-0.0609
50	281.5000	-0.0321
51	286.5000	0.6245
52	289.5000	0.8206
53	293.5000	1.0018
54	297.5000	0.8364
55	301.5000	1.2144
56	305.5000	0.9345
57	310.5000	0.6565
58	313.5000	0.9481
59	317.5000	0.1680
60	321.5000	0.4834
61	325.5000	-0.0556
62	329.5000	0.1476
63	333.5000	-0.0505
64	337.5000	0.3736
65	341.5000	-0.0295
66	345.5000	0.2167
67	349.5000	0.1344
68	351.5000	-0.1005
69	359.5000	-0.2389
70	363.5000	-0.7592
71	367.5000	-0.9170
72	371.5000	-0.7586
73	373.5000	-0.8970
74	377.5000	-1.3079
75	381.5000	-0.8792
76	385.5000	-1.0307
77	389.5000	-1.0985
78	393.6250	-0.3035
79	397.5000	-0.3920
80	401.5000	-0.2335
81	405.5000	-0.1777
82	409.5000	-0.0055
83	413.5000	-0.3469
84	417.5000	-0.0518
85	422.5000	-0.2334
86	426.5000	-0.3919
87	430.5000	-0.1351
88	434.5000	-0.5187
89	438.5000	-0.2887
90	442.5000	0.1284
91	446.5000	0.0845
92	450.5000	0.7752
93	454.5000	1.1407
94	458.5000	0.8090
95	462.5000	1.2743
96	466.5000	1.1251
97	470.5000	0.9297
98	474.5000	0.8581
99	478.5000	0.7030
100	482.5000	0.2595
101	486.5000	0.3372
102	490.5000	-0.1988
103	494.5000	-0.2286
104	498.5000	0.1401
105	507.5000	0.0271
106	521.5000	-0.0097
107	525.5000	-0.3877
108	529.5000	-0.5373
109	533.5000	-0.6428
110	537.5000	-0.7491
111	541.5000	-1.1932
112	545.5000	-0.8495
113	549.5000	-0.9622
114	553.5000	-0.9727
115	557.5000	-0.2525
116	561.5000	-0.6371

117	565.5000	-0.1555
118	569.5000	-0.0840
119	573.5000	0.0610
120	577.5000	0.2499
121	581.5000	0.0868
122	585.5250	0.0329
123	589.5000	-0.2413
124	593.5000	0.2322
125	597.5000	-0.3299
126	601.5000	0.1908
127	605.5000	0.1958
128	609.5000	0.3215
129	613.6250	0.5361
130	615.5000	1.1740
131	619.5000	1.0730
132	625.5000	1.1437
133	628.5000	1.2924
134	632.5000	0.9806
135	636.5000	1.2935
136	540.5000	1.0124
137	644.5000	0.3506
138	648.5000	0.3425
139	652.5000	-0.0373
140	656.5000	-0.3360
141	660.2500	-0.1553
142	664.5000	-0.1384

MULTIPLE REGRESSION GEOS 1

SELECTION 1

VARIABLE NO.	MEAN	STANDARD DEVIATION	CORRELATION X VS. Y	REGRESSION COEFFICIENT	STD. ERROR OF REG. COEF.	COMPUTED T VALUE
9	0.11462	1.57594	0.83835	0.34098	0.00905	37.68267
10	-0.02424	1.48806	-0.06838	-0.01434	0.00969	-1.47959
27	0.02810	0.33258	0.19415	0.40944	0.05922	6.91445
28	-0.01233	0.33263	0.07832	0.00298	0.06033	0.04947
39	-0.03475	0.34410	0.00175	0.19384	0.05640	3.43657
40	-0.03306	0.35337	-0.10086	0.01203	0.05716	0.21044
55	-0.06401	0.92311	0.48564	0.30298	0.01546	19.59809
56	-0.02547	0.93616	-0.02670	-0.03788	0.01530	-2.47516
DEPENDENT						
69	0.00114	0.65553				

INTERCEPT -0.02420

MULTIPLE CORRELATION 0.96854

STD. ERROR OF ESTIMATE 0.16796

ANALYSIS OF VARIANCE FOR THE REGRESSION

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F VALUE
ATTRIBUTABLE TO REGRESSION	8	56.83827	7.10478	251.83546
DEVIATION FROM REGRESSION	133	3.75220	0.02821	
TOTAL	141	60.59047		

				*****FREQUENCY DEPENDENT LOVE NUMBERS***** (ASSUMING 2ND DEGREE TIDES ONLY)				*****OCEAN TIDE PARAMETERS***** (ASSUMING 2ND DEGREE TIDES ONLY AND SOLID EARTH LOVE NUMBER K2=0.300 AND SOLID EARTH TIDAL LAG=0.0 DEG)			
L M P Q	TIDE	DIS.BODY	LOVE NUMBER	STD. ERROR	LAG ANGLE (DEGREES)	STD. ERROR (DEGREES)	C (CM)	STD. ERROR (CM)	PHASE (DEGREES)	STD. ERROR (DEGREES)
2 1 0-1		MOON	...	...	...	...	...	...	...	...
2 1 0 0	O1	MOON	...	...	...	...	...	...	...	...
2 1 0 1		MOON	...	...	...	...	...	...	...	...
2 1 1-1		MOON	...	...	...	...	...	...	...	...
2 1 1 0	K1	MOON+SUN	0.24178	0.00641	2.40751	1.62649	7.78612	0.84336	9.6549	6.6154
2 1 1 1		MOON	...	...	...	...	...	...	...	...
2 1 2-1		MOON	...	...	...	...	...	...	...	...
2 1 2 0		MOON	...	...	...	...	...	...	...	...
2 1 2 1		MOON	...	...	...	...	...	...	...	...
2 2 0-1		MOON	...	...	...	...	...	...	...	...
2 2 0 0	M2	MOON	...	...	...	...	...	...	...	...
2 2 0 1		MOON	...	...	...	...	...	...	...	...
2 2 1-1		MOON	...	...	...	...	...	...	...	...
2 2 1 0	K2	MOON+SUN	0.30395	0.04396	-0.41760	8.44130	0.07279	0.71074	119.3336	564.8974
2 2 1 1		MOON	...	...	...	...	...	...	...	...
2 2 2-1		MOON	...	...	...	...	...	...	...	...
2 2 2 0		MOON	...	...	...	...	...	...	...	...
2 2 2 1		MOON	...	...	...	...	...	...	...	...
2 1 0-1		SUN	...	...	...	...	...	...	...	...
2 1 0 0	P1	SUN	0.19421	0.05541	-3.55109	16.86308	4.27242	2.25596	173.5353	30.6499
2 1 0 1		SUN	...	...	...	...	...	...	...	...
2 1 1-1		SUN	...	...	...	...	...	...	...	...
2 1 1 0	K1S	SUN	...	...	...	...	...	...	...	...
2 1 1 1		SUN	...	...	...	...	...	...	...	...
2 1 2-1		SUN	...	...	...	...	...	...	...	...
2 1 2 0		SUN	...	...	...	...	...	...	...	...
2 1 2 1		SUN	...	...	...	...	...	...	...	...
2 2 0-1		SUN	...	...	...	...	...	...	...	...
2 2 0 0	S2	SUN	0.30534	0.01546	7.12637	2.87219	1.83083	0.73745	4.5006	23.3091
2 2 0 1		SUN	...	...	...	...	...	...	...	...
2 2 1-1		SUN	...	...	...	...	...	...	...	...
2 2 1 0	K2S	SUN	...	...	...	...	...	...	...	...
2 2 1 1		SUN	...	...	...	...	...	...	...	...
2 2 2-1		SUN	...	...	...	...	...	...	...	...
2 2 2 0		SUN	...	...	...	...	...	...	...	...
2 2 2 1		SUN	...	...	...	...	...	...	...	...

GEOS - 1 , 1966-1967 DATA

TIDAL INCLINATION

	TIME (JAN 1, 0 HRS UT = 1)	INCLINATION (ARCSEC)
1	0.370000D 02	-0.84447D 00
2	0.390000D 02	-0.92722D 00
3	0.410000D 02	-0.98710D 00
4	0.430000D 02	-0.10223D 01
5	0.450000D 02	-0.10320D 01
6	0.470000D 02	-0.10164D 01
7	0.490000D 02	-0.97713D 00
8	0.510000D 02	-0.91641D 00
9	0.530000D 02	-0.83763D 00
10	0.550000D 02	-0.74490D 00
11	0.570000D 02	-0.64203D 00
12	0.590000D 02	-0.53676D 00
13	0.610000D 02	-0.43159D 00
14	0.630000D 02	-0.33248D 00
15	0.650000D 02	-0.24412D 00
16	0.670000D 02	-0.17063D 00
17	0.690000D 02	-0.11531D 00
18	0.710000D 02	-0.80518D-01
19	0.730000D 02	-0.67559D-01
20	0.750000D 02	-0.76587D-01
21	0.770000D 02	-0.10662D 00
22	0.790000D 02	-0.15558D 00
23	0.810000D 02	-0.22039D 00
24	0.830000D 02	-0.29712D 00
25	0.850000D 02	-0.38118D 00
26	0.870000D 02	-0.46753D 00
27	0.890000D 02	-0.55095D 00
28	0.910000D 02	-0.62625D 00
29	0.930000D 02	-0.68855D 00
30	0.950000D 02	-0.73351D 00
31	0.970000D 02	-0.75753D 00
32	0.990000D 02	-0.75794D 00
33	0.101000D 03	-0.73310D 00
34	0.103000D 03	-0.68231D 00
35	0.105000D 03	-0.60679D 00
36	0.107000D 03	-0.50772D 00
37	0.109000D 03	-0.38807D 00
38	0.111000D 03	-0.25154D 00
39	0.113000D 03	-0.10254D 00
40	0.115000D 03	0.53999D-01
41	0.117000D 03	0.21286D 00
42	0.119000D 03	0.36879D 00
43	0.121000D 03	0.51671D 00
44	0.123000D 03	0.65200D 00
45	0.125000D 03	0.77063D 00
46	0.127000D 03	0.86939D 00
47	0.129000D 03	0.94602D 00
48	0.131000D 03	0.99923D 00
49	0.133000D 03	0.10286D 01
50	0.135000D 03	0.10355D 01
51	0.137000D 03	0.10211D 01
52	0.139000D 03	0.98814D 00
53	0.141000D 03	0.93998D 00
54	0.143000D 03	0.88002D 00
55	0.145000D 03	0.81257D 00
56	0.147000D 03	0.74137D 00
57	0.149000D 03	0.67091D 00
58	0.151000D 03	0.60409D 00
59	0.153000D 03	0.54410D 00
60	0.155000D 03	0.49320D 00
61	0.157000D 03	0.45284D 00
62	0.159000D 03	0.42363D 00
63	0.161000D 03	0.40328D 00
64	0.163000D 03	0.39555D 00
65	0.165000D 03	0.39583D 00
66	0.167000D 03	0.40029D 00
67	0.169000D 03	0.40701D 00
68	0.171000D 03	0.41256D 00
69	0.173000D 03	0.41385D 00
70	0.175000D 03	0.40727D 00
71	0.177000D 03	0.38996D 00
72	0.179000D 03	0.35948D 00
73	0.181000D 03	0.31402D 00
74	0.183000D 03	0.25259D 00
75	0.185000D 03	0.17510D 00
76	0.187000D 03	0.82343D-01
77	0.189000D 03	-0.23974D-01
78	0.191000D 03	-0.14130D 00
79	0.193000D 03	-0.26634D 00
80	0.195000D 03	-0.39524D 00
81	0.197000D 03	-0.52372D 00
82	0.199000D 03	-0.64731D 00
83	0.201000D 03	-0.76157D 00
84	0.203000D 03	-0.86230D 00
85	0.205000D 03	-0.94575D 00
86	0.207000D 03	-0.10089D 01
87	0.209000D 03	-0.10493D 01
88	0.211000D 03	-0.10659D 01
89	0.213000D 03	-0.10582D 01
90	0.215000D 03	-0.10270D 01
91	0.217000D 03	-0.97401D 00
92	0.219000D 03	-0.90204D 00
93	0.221000D 03	-0.81460D 00
94	0.223000D 03	-0.71590D 00
95	0.225000D 03	-0.61061D 00
96	0.227000D 03	-0.50366D 00
97	0.229000D 03	-0.39996D 00
98	0.231000D 03	-0.30418D 00
99	0.233000D 03	-0.22055D 00
100	0.235000D 03	-0.15251D 00
101	0.237000D 03	-0.10304D 00
102	0.239000D 03	-0.73567D-01
103	0.241000D 03	-0.64816D-01
104	0.243000D 03	-0.76326D-01
105	0.245000D 03	-0.10655D 00
106	0.247000D 03	-0.15292D 00
107	0.249000D 03	-0.21198D 00
108	0.251000D 03	-0.27958D 00
109	0.253000D 03	-0.35102D 00
110	0.255000D 03	-0.42133D 00
111	0.257000D 03	-0.48549D 00
112	0.259000D 03	-0.53870D 00
113	0.261000D 03	-0.57660D 00
114	0.263000D 03	-0.59548D 00
115	0.265000D 03	-0.59249D 00
116	0.267000D 03	-0.56578D 00
117	0.269000D 03	-0.51458D 00
118	0.271000D 03	-0.43926D 00
119	0.273000D 03	-0.34132D 00
120	0.275000D 03	-0.22331D 00
121	0.277000D 03	-0.83734D-01
122	0.279000D 03	0.58119D-01
123	0.281000D 03	0.21237D 00
124	0.283000D 03	0.36879D 00
125	0.285000D 03	0.52201D 00
126	0.287000D 03	0.66681D 00
127	0.289000D 03	0.79831D 00
128	0.291000D 03	0.91222D 00
129	0.293000D 03	0.10050D 01
130	0.295000D 03	0.10742D 01
131	0.297000D 03	0.11181D 01
132	0.299000D 03	0.11362D 01
133	0.301000D 03	0.11292D 01
134	0.303000D 03	0.10987D 01

135	0.305000D 03	0.10472D 01
136	0.307000D 03	0.97809D 00
137	0.309000D 03	0.89526D 00
138	0.311000D 03	0.80304D 00
139	0.313000D 03	0.70590D 00
140	0.315000D 03	0.60828D 00
141	0.317000D 03	0.51428D 00
142	0.319000D 03	0.42757D 00
143	0.321000D 03	0.35112D 00
144	0.323000D 03	0.23710D 00
145	0.325000D 03	0.23680D 00
146	0.327000D 03	0.20056D 00
147	0.329000D 03	0.17780D 00
148	0.331000D 03	0.15707D 00
149	0.333000D 03	0.16612D 00
150	0.335000D 03	0.17209D 00
151	0.337000D 03	0.18166D 00
152	0.339000D 03	0.19126D 00
153	0.341000D 03	0.19728D 00
154	0.343000D 03	0.19626D 00
155	0.345000D 03	0.18516D 00
156	0.347000D 03	0.16146D 00
157	0.349000D 03	0.12339D 00
158	0.351000D 03	0.69970D-01
159	0.353000D 03	0.11625D-02
160	0.355000D 03	-0.82167D-01
161	0.357000D 03	-0.17825D 00
162	0.359000D 03	-0.28450D 00
163	0.361000D 03	-0.39762D 00
164	0.363000D 03	-0.51378D 00
165	0.365000D 03	-0.62879D 00
166	0.367000D 03	-0.73832D 00
167	0.369000D 03	-0.83811D 00
168	0.371000D 03	-0.92421D 00
169	0.373000D 03	-0.99315D 00
170	0.375000D 03	-0.10421D 01
171	0.377000D 03	-0.10693D 01
172	0.379000D 03	-0.10735D 01
173	0.381000D 03	-0.10548D 01
174	0.383000D 03	-0.10141D 01
175	0.385000D 03	-0.95356D 00
176	0.387000D 03	-0.87586D 00
177	0.389000D 03	-0.78462D 00
178	0.391000D 03	-0.68401D 00
179	0.393000D 03	-0.57853D 00
180	0.395000D 03	-0.47286D 00
181	0.397000D 03	-0.37156D 00
182	0.399000D 03	-0.27891D 00
183	0.401000D 03	-0.19863D 00
184	0.403000D 03	-0.13374D 00
185	0.405000D 03	-0.86375D-01
186	0.407000D 03	-0.57713D-01
187	0.409000D 03	-0.47882D-01
188	0.411000D 03	-0.55963D-01
189	0.413000D 03	-0.80039D-01
190	0.415000D 03	-0.11729D 00
191	0.417000D 03	-0.16412D 00
192	0.419000D 03	-0.21637D 00
193	0.421000D 03	-0.26949D 00
194	0.423000D 03	-0.31882D 00
195	0.425000D 03	-0.35977D 00
196	0.427000D 03	-0.38810D 00
197	0.429000D 03	-0.40015D 00
198	0.431000D 03	-0.39297D 00
199	0.433000D 03	-0.36458D 00
200	0.435000D 03	-0.31397D 00
201	0.437000D 03	-0.24126D 00
202	0.439000D 03	-0.14765D 00
203	0.441000D 03	-0.35417D-01
204	0.443000D 03	0.92215D-01
205	0.445000D 03	0.23120D 00
206	0.447000D 03	0.37685D 00
207	0.449000D 03	0.52406D 00
208	0.451000D 03	0.66754D 00
209	0.453000D 03	0.80207D 00
210	0.455000D 03	0.92273D 00
211	0.457000D 03	0.10251D 01
212	0.459000D 03	0.11056D 01
213	0.461000D 03	0.11614D 01
214	0.463000D 03	0.11908D 01
215	0.465000D 03	0.11931D 01
216	0.467000D 03	0.11689D 01
217	0.469000D 03	0.11196D 01
218	0.471000D 03	0.10460D 01
219	0.473000D 03	0.95734D 00
220	0.475000D 03	0.85178D 00
221	0.477000D 03	0.73594D 00
222	0.479000D 03	0.61466D 00
223	0.481000D 03	0.49281D 00
224	0.483000D 03	0.37506D 00
225	0.485000D 03	0.26562D 00
226	0.487000D 03	0.16809D 00
227	0.489000D 03	0.85247D-01
228	0.491000D 03	0.18973D-01
229	0.493000D 03	-0.29848D-01
230	0.495000D 03	-0.61342D-01
231	0.497000D 03	-0.76612D-01
232	0.499000D 03	-0.77657D-01
233	0.501000D 03	-0.67248D-01
234	0.503000D 03	-0.48760D-01
235	0.505000D 03	-0.25978D-01
236	0.507000D 03	-0.28806D-02
237	0.509000D 03	0.16583D-01
238	0.511000D 03	0.28714D-01
239	0.513000D 03	0.30270D-01
240	0.515000D 03	0.18648D-01
241	0.517000D 03	-0.79722D-02
242	0.519000D 03	-0.50520D-01
243	0.521000D 03	-0.10898D 00
244	0.523000D 03	-0.18237D 00
245	0.525000D 03	-0.25882D 00
246	0.527000D 03	-0.36560D 00
247	0.529000D 03	-0.46934D 00
248	0.531000D 03	-0.57612D 00
249	0.533000D 03	-0.68171D 00
250	0.535000D 03	-0.78178D 00
251	0.537000D 03	-0.87212D 00
252	0.539000D 03	-0.94886D 00
253	0.541000D 03	-0.10086D 01
254	0.543000D 03	-0.10489D 01
255	0.545000D 03	-0.10677D 01
256	0.547000D 03	-0.10643D 01
257	0.549000D 03	-0.10389D 01
258	0.551000D 03	-0.99248D 00
259	0.553000D 03	-0.92716D 00
260	0.555000D 03	-0.84581D 00
261	0.557000D 03	-0.75196D 00
262	0.559000D 03	-0.64967D 00
263	0.561000D 03	-0.54329D 00
264	0.563000D 03	-0.43725D 00
265	0.565000D 03	-0.33591D 00
266	0.567000D 03	-0.24289D 00
267	0.569000D 03	-0.16184D 00
268	0.571000D 03	-0.95269D-01
269	0.573000D 03	-0.44926D-01
270	0.575000D 03	-0.11610D-01
271	0.577000D 03	0.48697D-02
272	0.579000D 03	0.56776D-02
273	0.581000D 03	-0.71097D-02
274	0.583000D 03	-0.30618D-01
275	0.585000D 03	-0.61327D-01
276	0.587000D 03	-0.95264D-01
277	0.589000D 03	-0.12821D 00
278	0.591000D 03	-0.15594D 00
279	0.593000D 03	-0.17442D 00
280	0.595000D 03	-0.18009D 00
281	0.597000D 03	-0.17000D 00
282	0.599000D 03	-0.14201D 00

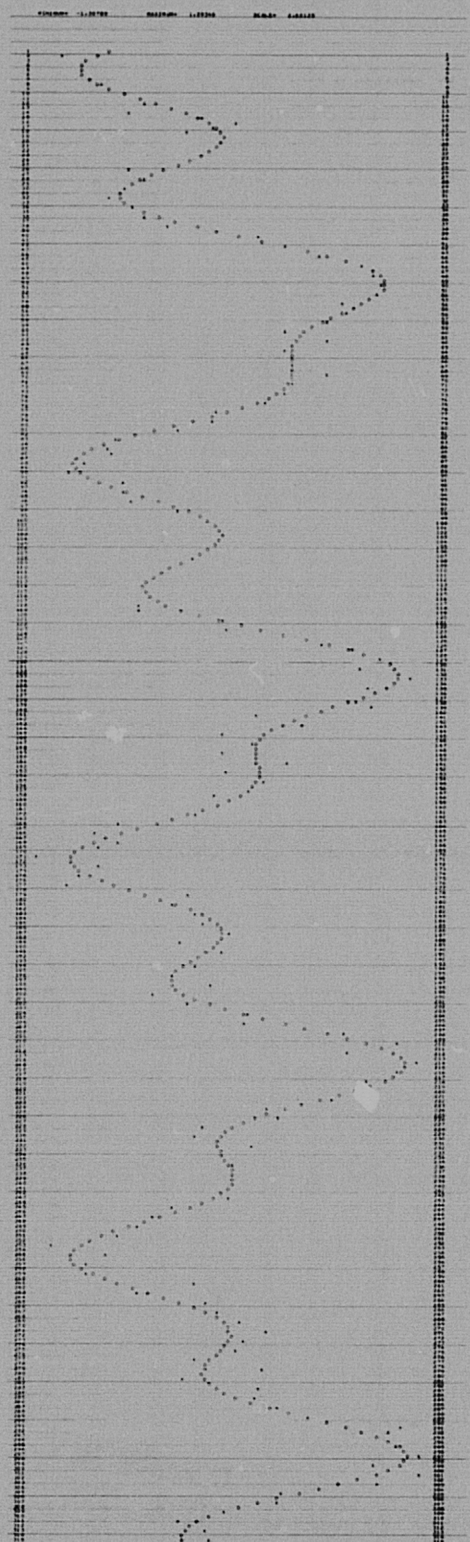
283	0.601000D 03	-0.94911D-01
284	0.603000D 03	-0.28518D-01
285	0.605000D 03	0.56308D-01
286	0.607000D 03	0.15768D 00
287	0.609000D 03	0.27275D 00
288	0.611000D 03	0.39784D 00
289	0.613000D 03	0.52851D 00
290	0.615000D 03	0.66024D 00
291	0.617000D 03	0.73769D 00
292	0.619000D 03	0.90590D 00
293	0.621000D 03	0.10100D 01
294	0.623000D 03	0.10958D 01
295	0.625000D 03	0.11595D 01
296	0.627000D 03	0.11982D 01
297	0.629000D 03	0.12103D 01
298	0.631000D 03	0.11950D 01
299	0.633000D 03	0.11527D 01
300	0.635000D 03	0.10849D 01
301	0.637000D 03	0.99407D 00
302	0.639000D 03	0.88382D 00
303	0.641000D 03	0.75832D 00
304	0.643000D 03	0.62237D 00
305	0.645000D 03	0.48107D 00
306	0.647000D 03	0.33966D 00
307	0.649000D 03	0.20317D 00
308	0.651000D 03	0.76287D-01
309	0.653000D 03	-0.36930D-01
310	0.655000D 03	-0.13320D 00
311	0.657000D 03	-0.21017D 00
312	0.659000D 03	-0.26651D 00
313	0.661000D 03	-0.30198D 00
314	0.663000D 03	-0.31738D 00
315	0.665000D 03	-0.31456D 00

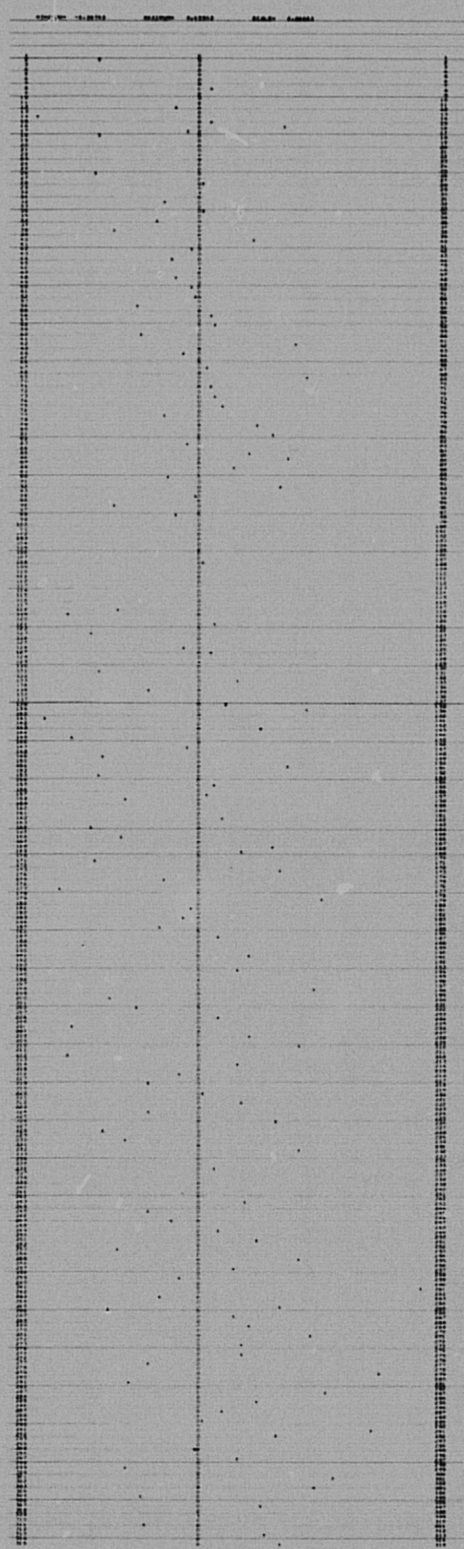
RESIDUALS

	TIME (JAN 1. 0 HRS UT = 1)	RESIDUAL (ARCSEC)
1	0.38500D 02	-0.25086D 00
2	0.51500D 02	0.11783D-02
3	0.58500D 02	-0.30058D-01
4	0.62500D 02	-0.34345D 00
5	0.64500D 02	0.39403D-01
6	0.66500D 02	0.19987D 00
7	0.68500D 02	-0.19324D-01
8	0.70500D 02	-0.22522D 00
9	0.86500D 02	-0.26029D 00
10	0.90500D 02	-0.93253D-02
11	0.94500D 02	-0.14703D-01
12	0.98500D 02	-0.31348D-01
13	0.10250D 03	0.24303D-01
14	0.10650D 03	-0.71563D-01
15	0.11050D 03	-0.16005D 00
16	0.11450D 03	0.15687D 00
17	0.11850D 03	0.16897D-01
18	0.12250D 03	-0.31648D-01
19	0.12650D 03	0.22092D-01
20	0.13050D 03	-0.45401D-01
21	0.13450D 03	-0.21787D-01
22	0.13950D 03	0.25852D-02
23	0.14350D 03	-0.12537D 00
24	0.14750D 03	0.41230D-01
25	0.15150D 03	0.45425D-01
26	0.15550D 03	-0.12518D 00
27	0.15950D 03	0.22156D 00
28	0.16338D 03	-0.37627D-01
29	0.16850D 03	0.12191D-01
30	0.17250D 03	0.23519D 00
31	0.17650D 03	0.19782D-01
32	0.18050D 03	0.21602D-01
33	0.18450D 03	0.27652D-01
34	0.18850D 03	-0.11328D 00
35	0.19250D 03	0.91712D-01
36	0.19650D 03	0.13028D 00
37	0.20050D 03	-0.57250D-01
38	0.20450D 03	0.91172D-01
39	0.20750D 03	0.20462D 00
40	0.21150D 03	0.72344D-01
41	0.21450D 03	-0.66743D-01
42	0.21850D 03	0.19400D 00
43	0.22250D 03	0.13795D-01
44	0.22650D 03	-0.16593D 00
45	0.23050D 03	-0.34658D-01
46	0.25050D 03	-0.14571D-01
47	0.27050D 03	-0.16729D 00
48	0.27350D 03	-0.32631D 00
49	0.27750D 03	-0.78618D-02
50	0.28150D 03	-0.28351D 00
51	0.28650D 03	-0.71779D-02
52	0.28950D 03	-0.79527D-02
53	0.29350D 03	-0.22845D-01
54	0.29750D 03	-0.23862D 00
55	0.30150D 03	0.90698D-01
56	0.30550D 03	-0.96965D-01
57	0.31050D 03	0.30156D-01
58	0.31350D 03	0.26672D 00
59	0.31750D 03	-0.32382D 00
60	0.32150D 03	0.14953D 00
61	0.32550D 03	-0.28199D 00
62	0.32950D 03	-0.26470D-01
63	0.33350D 03	-0.21755D 00
64	0.33750D 03	0.18943D 00
65	0.34150D 03	-0.22736D 00
66	0.34550D 03	0.35239D-01
67	0.34950D 03	0.22896D-01
68	0.35150D 03	-0.15465D 00
69	0.35950D 03	0.73423D-01
70	0.36350D 03	-0.21643D 00
71	0.36750D 03	-0.15267D 00
72	0.37150D 03	0.18453D 00
73	0.37350D 03	0.11034D 00
74	0.37750D 03	-0.23541D 00
75	0.38150D 03	0.16744D 00
76	0.38550D 03	-0.95137D-01
77	0.38950D 03	-0.23831D 00
78	0.39363D 03	0.24172D 00
79	0.39750D 03	-0.44596D-01
80	0.40150D 03	-0.52500D-01
81	0.40550D 03	-0.10026D 00
82	0.40950D 03	0.42823D-01
83	0.41350D 03	-0.25967D 00
84	0.41750D 03	0.12500D 00
85	0.42250D 03	0.73661D-01
86	0.42650D 03	-0.94663D-02
87	0.43050D 03	0.26136D 00
88	0.43450D 03	-0.18995D 00
89	0.43850D 03	-0.11577D 00
90	0.44250D 03	0.69304D-01
91	0.44650D 03	-0.25556D 00
92	0.45050D 03	0.14237D 00
93	0.45450D 03	0.24654D 00
94	0.45850D 03	-0.27859D 00
95	0.46250D 03	0.88329D-01
96	0.46650D 03	-0.52292D-01
97	0.47050D 03	-0.13815D 00
98	0.47450D 03	-0.21250D-01
99	0.47850D 03	0.57760D-01
100	0.48250D 03	-0.14436D 00
101	0.48650D 03	0.14598D 00
102	0.49050D 03	-0.23276D 00
103	0.49450D 03	-0.17359D 00
104	0.49850D 03	0.21869D 00
105	0.50750D 03	0.24645D-01
106	0.52150D 03	0.11631D 00
107	0.52550D 03	-0.95561D-01
108	0.52950D 03	-0.41341D-01
109	0.53350D 03	0.64590D-01
110	0.53750D 03	0.14364D 00
111	0.54150D 03	-0.17258D 00
112	0.54550D 03	0.21946D 00
113	0.54950D 03	0.65946D-01
114	0.55350D 03	-0.64475D-01
115	0.55750D 03	0.47448D 00
116	0.56150D 03	-0.12055D 00
117	0.56550D 03	0.15612D 00
118	0.56950D 03	0.59768D-01
119	0.57350D 03	0.95995D-01
120	0.57750D 03	0.24341D 00
121	0.58150D 03	0.98945D-01
122	0.58563D 03	0.10454D 00
123	0.58950D 03	-0.10547D 00
124	0.59350D 03	0.40940D 00
125	0.59750D 03	-0.16519D 00
126	0.60150D 03	0.27086D 00
127	0.60550D 03	0.10560D 00
128	0.60950D 03	0.18392D-01
129	0.61363D 03	-0.33752D-01
130	0.61650D 03	0.41751D 00
131	0.61950D 03	0.13356D 00
132	0.62550D 03	-0.27922D-01
133	0.62850D 03	0.82494D-01
134	0.63250D 03	-0.13509D 00

135	0.636500D 03	0.27472D 00	139	0.652500D 03	-0.27237D-01
136	0.640500D 03	0.22151D 00	140	0.656500D 03	-0.14315D 00
137	0.644500D 03	-0.15502D 00	141	0.660250D 03	0.13577D 00
138	0.648500D 03	0.10595D 00	142	0.664500D 03	0.17843D 00

SIGMA = SQRT((SUM OF SQUARES)/(MEXP-1)) = 0.16314





MULTIPLE REGRESSION GEOS 1

SELECTION 2

VARIABLE NO.	MEAN	STANDARD DEVIATION	CORRELATION X VS. Y	REGRESSION COEFFICIENT	STD. ERROR OF REG. COEF.	COMPUTED T VALUE
9	0.11462	1.57594	0.83835	0.33968	0.00699	48.57646
10	-0.02424	1.48806	-0.06838	-0.01588	0.00745	-2.12973
21	0.00660	0.41087	0.20756	0.25014	0.02680	9.33432
27	0.02810	0.33259	0.19415	0.38970	0.03493	11.15683
39	-0.03475	0.34410	0.00175	0.18491	0.03360	5.50297
55	-0.06401	0.92311	0.48564	0.29684	0.01200	24.73010
56	-0.02547	0.93616	-0.02570	-0.03398	0.01184	-2.87070
DEPENDENT 69	0.00114	0.65553				

INTERCEPT -0.02673

MULTIPLE CORRELATION 0.98105

STD. ERROR OF ESTIMATE 0.13028

ANALYSIS OF VARIANCE FOR THE REGRESSION

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F VALUE
ATTRIBUTABLE TO REGRESSION	7	58.31595	8.33085	490.79956
DEVIATION FROM REGRESSION	134	2.27452	0.01697	
TOTAL	141	60.59047		

****FREQUENCY DEPENDENT LOVE NUMBERS*****
(ASSUMING 2ND DEGREE TIDES ONLY)

*****OCEAN TIDE PARAMETERS*****
(ASSUMING 2ND DEGREE TIDES ONLY AND SOLID EARTH LOVE NUMBER K2=0.300 AND SOLID EARTH TIDAL LAG=0.0 DEG)

L M P Q	TIDE	DIS.BODY	LOVE NUMBER	STD. ERROR	LAG ANGLE (DEGREES)	STD. ERROR (DEGREES)	C (CM)	STD. ERROR (CM)	PHASE (DEGREES)	STD. ERROR (DEGREES)
2 1 0-1		MOON	...	...	...	...	...	...	...	...
2 1 0 0	O1	MOON	...	...	...	...	...	...	...	...
2 1 0 1		MOON	...	...	...	...	...	...	...	...
2 1 1-1		MOON	...	...	...	...	...	...	...	...
2 1 1 0	K1	MOON+SUN	0.24088	0.00495	2.67748	1.25557	7.93093	0.65155	10.7300	4.9983
2 1 1 1		MOON	...	...	...	...	...	...	...	...
2 1 2-1		MOON	...		...	...	...	...	...	...
2 1 2 0		MOON	...	...	...	...	...	...	...	...
2 1 2 1		MOON	...	...	...	...	...	...	...	...
2 2 0-1		MOON	...	...	...	...	...	...	...	...
2 2 0 0	M2	MOON	0.25014	0.02580	0.0	0.0	5.08532	2.73349	270.0000	0.0
2 2 0 1		MOON	...	...	...	...	...	...	...	...
2 2 1-1		MOON	...	...	...	...	...	...	...	...
2 2 1 0	K2	MOON+SUN	0.28926	0.02593	0.0	0.0	0.17294	0.41731	270.0000	0.0
2 2 1 1		MOON	...	...	...	...	...	...	...	...
2 2 2-1		MOON	...	...	...	...	...	...	...	...
2 2 2 0		MOON	...	...	...	...	...	...	...	...
2 2 2 1		MOON	...	...	...	...	...	...	...	...

L M P Q	TIDE	DIS.BODY	LOVE NUMBER	STD. ERROR	LAG ANGLE (DEGREES)	STD. ERROR (DEGREES)	C (CM)	STD. ERROR (CM)	PHASE (DEGREES)	STD. ERROR (DEGREES)
2 1 0-1		SUN	...	...	...	...	...	...	...	...
2 1 0 0	P1	SUN	0.18491	0.03360	0.0	0.0	4.60221	1.34373	180.0000	0.0
2 1 0 1		SUN	...	...	...	...	...	...	...	...
2 1 1-1		SUN	...	...	...	...	...	...	...	...
2 1 1 0	K1S	SUN	...	...	...	...	...	...	...	...
2 1 1 1		SUN	...	...	...	...	...	...	...	...
2 1 2-1		SUN	...	...	...	...	...	...	...	...
2 1 2 0		SUN	...	...	...	...	...	...	...	...
2 1 2 1		SUN	...	...	...	...	...	...	...	...
2 2 0-1		SUN	...	...	...	...	...	...	...	...
2 2 0 0	S2	SUN	0.29878	0.01200	6.52989	2.27016	1.64422	0.57037	354.6859	20.1514
2 2 0 1		SUN	...	...	...	...	...	...	...	...
2 2 1-1		SUN	...	...	...	...	...	...	...	...
2 2 1 0	K2S	SUN	...	...	...	...	...	...	...	...
2 2 1 1		SUN	...	...	...	...	...	...	...	...
2 2 2-1		SUN	...	...	...	...	...	...	...	...
2 2 2 0		SUN	...	...	...	...	...	...	...	...
2 2 2 1		SUN	...	...	...	...	...	...	...	...

GEOS - 1 , 1966-1967 DATA

TIDAL INCLINATION

	TIME (JAN 1, 0 HRS UT = 1)	INCLINATION (ARCSEC)
1	0.370000 02	-0.93285D 00
2	0.390000 02	-0.10479D 01
3	0.410000 02	-0.99536D 00
4	0.430000 02	-0.89187D 00
5	0.450000 02	-0.88345D 00
6	0.470000 02	-0.99117D 00
7	0.490000 02	-0.10892D 01
8	0.510000 02	-0.10384D 01
9	0.530000 02	-0.83505D 00
10	0.550000 02	-0.61783D 00
11	0.570000 02	-0.52611D 00
12	0.590000 02	-0.55791D 00
13	0.610000 02	-0.57694D 00
14	0.630000 02	-0.46095D 00
15	0.650000 02	-0.23524D 00
16	0.670000 02	-0.50538D-01
17	0.690000 02	-0.28961D-01
18	0.710000 02	-0.13817D 00
19	0.730000 02	-0.22840D 00
20	0.750000 02	-0.19085D 00
21	0.770000 02	-0.72359D-01
22	0.790000 02	-0.25230D-01
23	0.810000 02	-0.14510D 00
24	0.830000 02	-0.36736D 00
25	0.850000 02	-0.53132D 00
26	0.870000 02	-0.54465D 00
27	0.890000 02	-0.47556D 00
28	0.910000 02	-0.47500D 00
29	0.930000 02	-0.61675D 00
30	0.950000 02	-0.80827D 00
31	0.970000 02	-0.89055D 00
32	0.990000 02	-0.79784D 00
33	0.101000 03	-0.62514D 00
34	0.103000 03	-0.32659D 00
35	0.105000 03	-0.55327D 00
36	0.107000 03	-0.59944D 00
37	0.109000 03	-0.51609D 00
38	0.111000 03	-0.26998D 00
39	0.113000 03	0.17692D-01
40	0.115000 03	0.19440D 00
41	0.117000 03	0.23179D 00
42	0.119000 03	0.25037D 00
43	0.121000 03	0.33758D 00
44	0.123000 03	0.64827D 00
45	0.125000 03	0.89498D 00
46	0.127000 03	0.98851D 00
47	0.129000 03	0.93102D 00
48	0.131000 03	0.86150D 00
49	0.133000 03	0.90828D 00
50	0.135000 03	0.10538D 01
51	0.137000 03	0.11538D 01
52	0.139000 03	0.10907D 01
53	0.141000 03	0.89962D 00
54	0.143000 03	0.73466D 00
55	0.145000 03	0.71053D 00
56	0.147000 03	0.78576D 00
57	0.149000 03	0.81036D 00
58	0.151000 03	0.68735D 00
59	0.153000 03	0.47521D 00
60	0.155000 03	0.34122D 00
61	0.157000 03	0.36731D 00
62	0.159000 03	0.48595D 00
63	0.161000 03	0.54000D 00
64	0.163000 03	0.45066D 00
65	0.165000 03	0.29540D 00
66	0.167000 03	0.24041D 00
67	0.169000 03	0.32609D 00
68	0.171000 03	0.43853D 00
69	0.173000 03	0.53924D 00
70	0.175000 03	0.43251D 00
71	0.177000 03	0.27078D 00
72	0.179000 03	0.20403D 00
73	0.181000 03	0.26967D 00
74	0.183000 03	0.35143D 00
75	0.185000 03	0.30066D 00
76	0.187000 03	0.92440D-01
77	0.189000 03	-0.14740D 00
78	0.191000 03	-0.27299D 00
79	0.193000 03	-0.26931D 00
80	0.195000 03	-0.26482D 00
81	0.197000 03	-0.39258D 00
82	0.199000 03	-0.64622D 00
83	0.201000 03	-0.88225D 00
84	0.203000 03	-0.96656D 00
85	0.205000 03	-0.91137D 00
86	0.207000 03	-0.85865D 00
87	0.209000 03	-0.92782D 00
88	0.211000 03	-0.10879D 01
89	0.213000 03	-0.11888D 01
90	0.215000 03	-0.11188D 01
91	0.217000 03	-0.92257D 00
92	0.219000 03	-0.75611D 00
93	0.221000 03	-0.72516D 00
94	0.223000 03	-0.77755D 00
95	0.225000 03	-0.76209D 00
96	0.227000 03	-0.59216D 00
97	0.229000 03	-0.34154D 00
98	0.231000 03	-0.17168D 00
99	0.233000 03	[illegible]
100	0.235000 03	[illegible]
101	0.237000 03	-0.26305D 00
102	0.239000 03	-0.14479D 00
103	0.241000 03	0.13031D-01
104	0.243000 03	0.55334D-01
105	0.245000 03	-0.71177D-01
106	0.247000 03	-0.26049D 00
107	0.249000 03	-0.35627D 00
108	0.251000 03	-0.31294D 00
109	0.253000 03	-0.23960D 00
110	0.255000 03	-0.28039D 00
111	0.257000 03	-0.45873D 00
112	0.259000 03	-0.64712D 00
113	0.261000 03	-0.69689D 00
114	0.263000 03	-0.59013D 00
115	0.265000 03	-0.45491D 00
116	0.267000 03	-0.42777D 00
117	0.269000 03	-0.50834D 00
118	0.271000 03	-0.55896D 00
119	0.273000 03	-0.44972D 00
120	0.275000 03	-0.19658D 00
121	0.277000 03	0.52979D-01
122	0.279000 03	0.17158D 00
123	0.281000 03	0.18166D 00
124	0.283000 03	0.22714D 00
125	0.285000 03	0.41688D 00
126	0.287000 03	0.70498D 00
127	0.289000 03	0.93384D 00
128	0.291000 03	0.99508D 00
129	0.293000 03	0.93921D 00
130	0.295000 03	0.91905D 00
131	0.297000 03	0.10264D 01
132	0.299000 03	0.11939D 01
133	0.301000 03	0.12655D 01
134	0.303000 03	0.11607D 01

135	0.30500D 03	0.96109D 00
136	0.30700D 03	0.82587D 00
137	0.30900D 03	0.83158D 00
138	0.31100D 03	0.88868D 00
139	0.31300D 03	0.84675D 00
140	0.31500D 03	0.65313D 00
141	0.31700D 03	0.41358D 00
142	0.31900D 03	0.23524D 00
143	0.32100D 03	0.31496D 00
144	0.32300D 03	0.39303D 00
145	0.32500D 03	0.37077D 00
146	0.32700D 03	0.21815D 00
147	0.32900D 03	0.55810D-01
148	0.33100D 03	0.27717D-01
149	0.33300D 03	0.14841D 00
150	0.33500D 03	0.28560D 00
151	0.33700D 03	0.29654D 00
152	0.33900D 03	0.17490D 00
153	0.34100D 03	0.53974D-01
154	0.34300D 03	0.63025D-01
155	0.34500D 03	0.18799D 00
156	0.34700D 03	0.28330D 00
157	0.34900D 03	0.22246D 00
158	0.35100D 03	0.29318D-01
159	0.35300D 03	-0.14798D 00
160	0.35500D 03	-0.17283D 00
161	0.35700D 03	-0.14197D 00
162	0.35900D 03	-0.14514D 00
163	0.36100D 03	-0.30510D 00
164	0.36300D 03	-0.56642D 00
165	0.36500D 03	-0.75999D 00
166	0.36700D 03	-0.81626D 00
167	0.36900D 03	-0.76565D 00
168	0.37100D 03	-0.77086D 00
169	0.37300D 03	-0.91242D 00
170	0.37500D 03	-0.11106D 01
171	0.37700D 03	-0.12065D 01
172	0.37900D 03	-0.11271D 01
173	0.38100D 03	-0.96124D 00
174	0.38300D 03	-0.86585D 00
175	0.38500D 03	-0.90212D 00
176	0.38700D 03	-0.97293D 00
177	0.38900D 03	-0.92775D 00
178	0.39100D 03	-0.72441D 00
179	0.39300D 03	-0.47748D 00
180	0.39500D 03	-0.34223D 00
181	0.39700D 03	-0.35593D 00
182	0.39900D 03	-0.40318D 00
183	0.40100D 03	-0.34141D 00
184	0.40300D 03	-0.15450D 00
185	0.40500D 03	0.27271D-01
186	0.40700D 03	0.62092D-01
187	0.40900D 03	-0.55487D-01
188	0.41100D 03	-0.18899D 00
189	0.41300D 03	-0.20257D 00
190	0.41500D 03	-0.10243D 00
191	0.41700D 03	-0.26872D-01
192	0.41900D 03	-0.98107D-01
193	0.42100D 03	-0.28929D 00
194	0.42300D 03	-0.44814D 00
195	0.42500D 03	-0.45355D 00
196	0.42700D 03	-0.33683D 00
197	0.42900D 03	-0.24596D 00
198	0.43100D 03	-0.28590D 00
199	0.43300D 03	-0.40524D 00
200	0.43500D 03	-0.44836D 00
201	0.43700D 03	-0.31807D 00
202	0.43900D 03	-0.77888D-01
203	0.44100D 03	0.11360D 00
204	0.44300D 03	0.16730D 00
205	0.44500D 03	0.15412D 00
206	0.44700D 03	0.22648D 00
207	0.44900D 03	0.45347D 00
208	0.45100D 03	0.74314D 00
209	0.45300D 03	0.93406D 00
210	0.45500D 03	0.95985D 00
211	0.45700D 03	0.91414D 00
212	0.45900D 03	0.94779D 00
213	0.46100D 03	0.11066D 01
214	0.46300D 03	0.12804D 01
215	0.46500D 03	0.13171D 01
216	0.46700D 03	0.11821D 01
217	0.46900D 03	0.99473D 00
218	0.47100D 03	0.90468D 00
219	0.47300D 03	0.93674D 00
220	0.47500D 03	0.96822D 00
221	0.47700D 03	0.86190D 00
222	0.47900D 03	0.61485D 00
223	0.48100D 03	0.36521D 00
224	0.48300D 03	0.25575D 00
225	0.48500D 03	0.28142D 00
226	0.48700D 03	0.30575D 00
227	0.48900D 03	0.20391D 00
228	0.49100D 03	-0.21980D-02
229	0.49300D 03	-0.16509D 00
230	0.49500D 03	-0.16583D 00
231	0.49700D 03	-0.39132D-01
232	0.49900D 03	0.62130D-01
233	0.50100D 03	0.25778D-01
234	0.50300D 03	-0.10436D 00
235	0.50500D 03	-0.17780D 00
236	0.50700D 03	-0.99264D-01
237	0.50900D 03	0.67246D-01
238	0.51100D 03	0.16192D 00
239	0.51300D 03	0.93572D-01
240	0.51500D 03	-0.67660D-01
241	0.51700D 03	-0.16661D 00
242	0.51900D 03	-0.12803D 00
243	0.52100D 03	-0.36655D-01
244	0.52300D 03	-0.48088D-01
245	0.52500D 03	-0.22428D 00
246	0.52700D 03	-0.46654D 00
247	0.52900D 03	-0.61670D 00
248	0.53100D 03	-0.62011D 00
249	0.53300D 03	-0.57928D 00
250	0.53500D 03	-0.64195D 00
251	0.53700D 03	-0.84153D 00
252	0.53900D 03	-0.10578D 01
253	0.54100D 03	-0.11395D 01
254	0.54300D 03	-0.10601D 01
255	0.54500D 03	-0.94318D 00
256	0.54700D 03	-0.93046D 00
257	0.54900D 03	-0.10322D 01
258	0.55100D 03	-0.11164D 01
259	0.55300D 03	-0.10485D 01
260	0.55500D 03	-0.83524D 00
261	0.55700D 03	-0.61989D 00
262	0.55900D 03	-0.53544D 00
263	0.56100D 03	-0.56856D 00
264	0.56300D 03	-0.57791D 00
265	0.56500D 03	-0.44712D 00
266	0.56700D 03	-0.21137D 00
267	0.56900D 03	-0.24249D-01
268	0.57100D 03	0.39023D-03
269	0.57300D 03	-0.74416D-01
270	0.57500D 03	-0.15590D 00
271	0.57700D 03	-0.82815D-01
272	0.57900D 03	0.68000D-01
273	0.58100D 03	0.14261D 00
274	0.58300D 03	0.53789D-01
275	0.58500D 03	-0.12451D 00
276	0.58700D 03	-0.23149D 00
277	0.58900D 03	-0.18473D 00
278	0.59100D 03	-0.62743D-01
279	0.59300D 03	-0.18282D-01
280	0.59500D 03	-0.11377D 00
281	0.59700D 03	-0.25218D 00
282	0.59900D 03	-0.27612D 00

283	0.60100D 03	-0.13120D 00
284	0.60300D 03	0.77951D-01
285	0.60500D 03	0.19797D 00
286	0.60700D 03	0.18719D 00
287	0.60900D 03	0.15764D 00
288	0.61100D 03	0.25449D 00
289	0.61300D 03	0.49984D 00
290	0.61500D 03	0.76525D 00
291	0.61700D 03	0.90207D 00
292	0.61900D 03	0.89280D 00
293	0.62100D 03	0.86453D 00
294	0.62300D 03	0.95056D 00
295	0.62500D 03	0.11459D 01
296	0.62700D 03	0.13091D 01
297	0.62900D 03	0.13077D 01
298	0.63100D 03	0.11564D 01
299	0.63300D 03	0.10000D 01
300	0.63500D 03	0.96233D 00
301	0.63700D 03	0.10167D 01
302	0.63900D 03	0.10171D 01
303	0.64100D 03	0.85444D 00
304	0.64300D 03	0.57598D 00
305	0.64500D 03	0.33986D 00
306	0.64700D 03	0.25401D 00
307	0.64900D 03	0.26777D 00
308	0.65100D 03	0.23010D 00
309	0.65300D 03	0.53020D-01
310	0.65500D 03	-0.19187D 00
311	0.65700D 03	-0.34539D 00
312	0.65900D 03	-0.32581D 00
313	0.66100D 03	-0.21341D 00
314	0.66300D 03	-0.16576D 00
315	0.66500D 03	-0.25276D 00

RESIDUALS

	TIME (JAN 1, 0 HRS UT = 1)	RESIDUAL (ARCSEC)
1	0.38500D 02	-0.12304D 00
2	0.51500D 02	0.10108D 00
3	0.58500D 02	-0.48800D-01
4	0.62500D 02	-0.19568D 00
5	0.64500D 02	0.69044D-01
6	0.66500D 02	0.96604D-01
7	0.68500D 02	-0.12869D 00
8	0.70500D 02	-0.20630D 00
9	0.86500D 02	-0.15200D 00
10	0.90500D 02	-0.15501D 00
11	0.94500D 02	0.25998D-01
12	0.98500D 02	-0.69762D-02
13	0.10250D 03	-0.13459D 00
14	0.10650D 03	-0.10945D-01
15	0.11050D 03	-0.10503D 00
16	0.11450D 03	0.61174D-02
17	0.11850D 03	0.10362D 00
18	0.12250D 03	0.10348D-01
19	0.12650D 03	-0.11361D 00
20	0.13050D 03	0.71618D-01
21	0.13450D 03	-0.10172D-02
22	0.13950D 03	-0.69990D-01
23	0.14350D 03	0.24246D-01
24	0.14750D 03	-0.37703D-01
25	0.15150D 03	-0.36564D-02
26	0.15550D 03	0.24486D-01
27	0.15950D 03	0.12848D 00
28	0.16338D 03	-0.64033D-01
29	0.16850D 03	0.11678D 00
30	0.17250D 03	0.10729D 00
31	0.17650D 03	0.10793D 00
32	0.18050D 03	0.10317D 00
33	0.18450D 03	-0.10656D 00
34	0.18850D 03	-0.15708D-01
35	0.19250D 03	0.13396D 00
36	0.19650D 03	-0.16039D-01
37	0.20050D 03	0.42705D-01
38	0.20450D 03	0.95979D-01
39	0.20750D 03	0.46182D-01
40	0.21150D 03	0.13120D 00
41	0.21450D 03	0.49135D-01
42	0.21850D 03	0.59120D-01
43	0.22250D 03	0.37114D-01
44	0.22650D 03	-0.48482D-01
45	0.23050D 03	-0.16252D 00
46	0.25050D 03	0.56112D-01
47	0.27050D 03	-0.59548D-01
48	0.27350D 03	-0.24435D 00
49	0.27750D 03	-0.15788D 00
50	0.28150D 03	-0.21563D 00
51	0.28650D 03	-0.73299D-02
52	0.28950D 03	-0.14517D 00
53	0.29350D 03	0.75860D-01
54	0.29750D 03	-0.18205D 00
55	0.30150D 03	-0.40936D-01
56	0.30550D 03	0.18570D-01
57	0.31050D 03	-0.21420D-01
58	0.31350D 03	0.13725D 00
59	0.31750D 03	-0.19840D 00
60	0.32150D 03	0.14694D 00
61	0.32550D 03	-0.39772D 00
62	0.32950D 03	0.11497D 00
63	0.33350D 03	-0.23843D 00
64	0.33750D 03	0.98545D-01
65	0.34150D 03	-0.71124D-01
66	0.34550D 03	-0.45186D-02
67	0.34950D 03	-0.47574D-01
68	0.35150D 03	-0.77511D-01
69	0.35950D 03	-0.69183D-01
70	0.36350D 03	-0.13032D 00
71	0.36750D 03	-0.10990D 00
72	0.37150D 03	0.35229D-01
73	0.37350D 03	0.65749D-01
74	0.37750D 03	-0.10368D 00
75	0.38150D 03	0.46510D-01
76	0.38550D 03	-0.10785D 00
77	0.38950D 03	-0.20894D 00
78	0.39363D 03	0.11446D 00
79	0.39750D 03	-0.20925D-01
80	0.40150D 03	0.69731D-01
81	0.40550D 03	-0.23070D 00
82	0.40950D 03	0.38635D-01
83	0.41350D 03	-0.16261D 00
84	0.41750D 03	-0.22908D-01
85	0.42250D 03	0.18703D 00
86	0.42650D 03	-0.21865D-01
87	0.43050D 03	0.12852D 00
88	0.43450D 03	-0.66129D-01
89	0.43850D 03	-0.14900D 00
90	0.44250D 03	-0.37105D-01
91	0.44650D 03	-0.10931D 00
92	0.45050D 03	0.10105D 00
93	0.45450D 03	0.17462D 00
94	0.45850D 03	-0.11752D 00
95	0.46250D 03	0.29441D-01
96	0.46650D 03	-0.10224D 00
97	0.47050D 03	0.15986D-01
98	0.47450D 03	-0.11130D 00
99	0.47850D 03	0.19365D-01
100	0.48250D 03	-0.79792D-02
101	0.48650D 03	0.28665D-01
102	0.49050D 03	-0.25079D 00
103	0.49450D 03	-0.46752D-01
104	0.49850D 03	0.92495D-01
105	0.50750D 03	0.87230D-01
106	0.52150D 03	0.15066D-01
107	0.52550D 03	-0.10258D 00
108	0.52950D 03	0.92388D-01
109	0.53350D 03	-0.61784D-01
110	0.53750D 03	0.15171D 00
111	0.54150D 03	-0.61282D-01
112	0.54550D 03	0.77340D-01
113	0.54950D 03	0.99287D-01
114	0.55350D 03	0.32104D-01
115	0.55750D 03	0.33147D 00
116	0.56150D 03	-0.57654D-01
117	0.56550D 03	0.23752D 00
118	0.56950D 03	-0.82417D-01
119	0.57350D 03	0.18009D 00
120	0.57750D 03	0.29678D 00
121	0.58150D 03	-0.48794D-01
122	0.58563D 03	0.20521D 00
123	0.58950D 03	-0.85949D-01
124	0.59350D 03	0.26254D 00
125	0.59750D 03	-0.55108D-01
126	0.60150D 03	0.26917D 00
127	0.60530D 03	-0.19545D-01
128	0.60950D 03	0.13546D 00
129	0.61363D 03	-0.52760D-01
130	0.61650D 03	0.29010D 00
131	0.61950D 03	0.19199D 00
132	0.62550D 03	-0.52828D-01
133	0.62450D 03	-0.33337D-01
134	0.63250D 03	-0.50159D-01
135	0.63650D 03	0.29172D 00
136	0.64030D 03	0.10171D 00

137	0.64450D 03	-0.36023D-01	140	0.65650D 03	-0.13216D-01
138	0.64850D 03	0.79508D-01	141	0.66025D 03	0.10085D 00
139	0.65250D 03	-0.14542D 00	142	0.66450D 03	0.82549D-01

SIGMA = SQRT((SUM OF SQUARES)/(MEXP-1)) = 0.12702

Table 1

Orbital Data for the BE-C, GEOS-I, and GEOS-II Satellites

Satellite	Semimajor Axis (10^8 cm)	Inclination (degrees)	Eccentricity	Nodal Rate (degrees/day)
BE-C	7.5022	41.1667	0.025	-4.2535
GEOS-I	8.0729	59.3805	0.073	-2.2465
GEOS-II	7.7052	105.7896	0.033	1.3997

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Table 2

Tidal Parameters Derived from the Multiple Linear Regression Analyses of the Tidal Perturbations in the Orbital Inclinations of the BE-C, GEOS-I, and GEOS-II Satellites
(The errors indicated are the formal statistical errors.)

Satellite	Tide	ℓmpq	Period (days)	Amplitude (arc sec)	c_{2mp0}	s_{2mp0}	d_{2mp0}	δ_{2mp0} (deg)	C^+_{2m} (cm)	ϵ^+_{2m} (deg)
BE-C	O_1	2100	11.8	0.09	0.276 ± 0.077	-0.018 ± 0.088	0.28 ± 0.08	- 3.6 ± 18.1	3.0 ± 8.1	144 ± 163
	K_1	2110	84.8	0.80	0.254 ± 0.010	0.025 ± 0.007	0.26 ± 0.01	5.7 ± 1.6	6.9 ± 1.2	29 ± 8
	M_2	2200	10.3	0.11	0.204 ± 0.053	0.030 ± 0.054	0.21 ± 0.05	8.4 ± 15.1	10.3 ± 5.4	287 ± 31
	K_2	2210	42.4	0.12	0.322 ± 0.065	0.128 ± 0.072	0.35 ± 0.06	21.7 ± 11.6	2.1 ± 1.2	10 ± 28
	P_1	2100	57.8	0.13	0.205 ± 0.036	-0.016 ± 0.041	0.21 ± 0.04	- 4.5 ± 11.4	3.8 ± 1.5	170 ± 24
	S_2	2200	34.4	0.20	0.253 ± 0.030	0.025 ± 0.030	0.25 ± 0.03	5.6 ± 6.8	2.5 ± 1.4	298 ± 33
GEOS-I	O_1	2100	12.6	–	–	–	–	–	–	–
	K_1	2110	160.8	0.73	0.241 ± 0.005	0.011 ± 0.005	0.24 ± 0.01	2.7 ± 1.3	7.9 ± 0.7	11 ± 5
	M_2	2200	11.7	0.15	0.251 ± 0.027	0.017 ± 0.027	0.25 ± 0.03	3.9 ± 6.1	5.3 ± 2.8	289 ± 29
	K_2	2210	80.4	0.18	0.284 ± 0.034	0.000 ± 0.035	0.28 ± 0.03	0.0 ± 7.1	0.3 ± 0.6	270 ± 122
	P_1	2100	85.4	0.09	0.181 ± 0.044	0.010 ± 0.045	0.18 ± 0.04	3.3 ± 14.2	4.8 ± 1.8	185 ± 22
	S_2	2200	55.7	0.39	0.297 ± 0.012	0.034 ± 0.012	0.30 ± 0.01	6.6 ± 2.3	1.7 ± 0.6	355 ± 20
GEOS-II	O_1	2100	14.4	–	–	–	–	–	–	–
	K_1	2110	255.4	0.81	0.257 ± 0.021	-0.046 ± 0.013	0.26 ± 0.02	-10.2 ± 2.7	8.4 ± 2.2	313 ± 16
	M_2	2200	15.3	0.25	0.242 ± 0.025	0.050 ± 0.025	0.25 ± 0.02	11.7 ± 5.7	7.8 ± 2.5	311 ± 18
	K_2	2210	127.7	0.44	0.306 ± 0.023	0.012 ± 0.029	0.31 ± 0.02	2.2 ± 5.3	0.2 ± 0.5	28 ± 105
	P_1	2100	629.8	0.28	0.050 ± 0.022	-0.107 ± 0.037	0.12 ± 0.03	-65.0 ± 12.3	10.9 ± 1.0	157 ± 7
	S_2	2200	434.7	4.58	0.340 ± 0.007	-0.015 ± 0.004	0.34 ± 0.01	- 2.5 ± 0.6	2.1 ± 0.3	111 ± 6

Table 3

Secular Changes in the Moon's Orbit and the Earth's Orientation and Spin, and the Dissipation of Energy for Selected Tides (The entries are a weighted average over all three satellites The errors indicated are the formal statistical errors)

$\dot{X}$ \ ℓmpq	$[X]_{\ell mpq}$ (Moon) 2100	2110	2200	2210	$[X]_{\ell mpq}$ (Sun) 2100	2110	2200	2210
$\dot{n}_M$ (arc sec/(100 yr)^2)	3 ± 13	0	-29 ± 15	0	–	–	–	–
$\dot{a}_M$ (cm/yr)	-0.4 ± 1.9	0	4.3 ± 2.2	0	–	–	–	–
$\dot{e}_M$ (/10^9 yr)	0.0 ± 0.001	0	-0.002 ± 0.001	0	–	–	–	–
$\dot{j}$ (deg/10^9 yr)	-0.3 ± 1.5	-0.2 ± 0.1	-0.7 ± 0.3	- 0.0 ± 0.1	–	–	–	–
$\dot{i}_s$ (deg/10^9 yr)	-1.9 ± 9.2	-0.7 ± 0.3	3.2 ± 1.6	-0.1 ± 0.2	-1.0 ± 0.5	-0.2 ± 0.1	-0.2 ± 0.1	-0.0 ± 0.1
$\ddot{\theta}$ (10^{-22} rad/sec^2)	0.3 ± 1.4	-0.1 ± 0.1	-6.3 ± 3.2	-0.0 ± 0.1	0.1 ± 0.1	-0.0 ± 0.1	+0.4 ± 0.2	-0.0 ± 0.1
$\dot{E}$ (10^{19} erg/sec)	0.1 ± 0.7	-0.1 ± 0.1	-3.6 ± 1.8	-0.0 ± 0.1	0.1 ± 0.1	-0.0 ± 0.1	+0.2 ± 0.1	-0.0 ± 0.1

Table 4

Secular Changes in the Moon's Orbit and the Earth's Orientation and Spin, and the Dissipation of Energy for Selected Tides
(The entries are a weighted average over the BE-C and GEOS-I satellites
The errors indicated are the formal statistical errors)

$\dot{X}$ \ ℓmpq	$[X]_{\ell mpq}$ (Moon) 2100	2110	2200	2210	$[X]_{\ell mpq}$ (Sun) 2100	2110	2200	2210
$\dot{n}_M$ (arc sec/(100 yr)^2)	3 ± 13	0	-17 ± 20	0	–	–	–	–
$\dot{a}_M$ (cm/yr)	-0.4 ± 1.9	0	2.4 ± 3.0	0	–	–	–	–
$\dot{e}_M$ (/10^9 yr)	0.0 ± 0.001	0	-0.001 ± 0.001	0	–	–	–	–
$\dot{j}$ (deg/10^9 yr)	-0.3 ± 1.5	-0.3 ± 0.1	-0.4 ± 0.5	-0.0 ± 0.1	–	–	–	–
$\dot{i}_s$ (deg/10^9 yr)	-1.9 ± 9.2	-1.3 ± 0.3	1.8 ± 2.3	-0.2 ± 0.2	-0.1 ± 0.7	-0.3 ± 0.1	0.7 ± 0.2	-0.0 ± 0.1
$\ddot{\theta}$ (10^{-22} rad/sec^2)	0.3 ± 1.4	-0.2 ± 0.1	-3.6 ± 4.4	-0.0 ± 0.1	0.0 ± 0.1	-0.0 ± 0.1	-1.3 ± 0.4	-0.0 ± 0.1
$\dot{E}$ (10^{19} erg/sec)	0.1 ± 0.7	-0.1 ± 0.1	-2.0 ± 2.5	-0.0 ± 0.1	0.0 ± 0.1	-0.0 ± 0.1	-0.7 ± 0.3	-0.0 ± 0.1

Table 5

$P_{\ell mpq}$ for $\ell = 2$, $q = 0$ for the Quantities Shown in the Left-Hand Column

ℓmpq / $\dot{X}$	$P_{\ell mpq}$ (Moon) 2100	2110	2120	2200	2210	2220	$P_{\ell mpq}$ (Sun) 2100	2110	2120	2200	2210	2220
$\dot{n}_M$ (arc sec/(100 yr)^2)	-144.6	0	+0.3	-847.1	0	+0.0	–	–	–	–	–	–
$\dot{a}_M$ (cm/yr)	+ 21.4	0	-0.0	+125.1	0	-0.0	–	–	–	–	–	–
$\dot{e}_M$ (/10^9 yr)	- 0.0076	0	+0.0	- 0.0447	0	+0.0	–	–	–	–	–	–
$\dot{j}$ (deg/10^9 yr)	+ 16.7	-18.2	-0.1	- 19.4	-1.9	-0.0	–	–	–	–	–	–
$\dot{i}_s$ (deg/10^9 yr)	+105.3	-81.0	-0.6	+ 94.0	-8.4	-0.0	+22.5	-17.5	-0.1	+19.9	-1.6	-0.0
$\ddot{\theta}$ (10^{-22} rad/sec^2)	- 15.6	-14.2	-0.0	-182.8	-1.5	-0.0	- 3.3	- 3.1	-0.0	-38.7	-0.3	-0.0
$\dot{E}$ (10^{19} erg/sec)	- 8.5	- 8.3	-0.0	-103.6	-0.9	-0.0	- 2.0	- 1.8	-0.0	-22.8	-0.2	-0.0

C.2

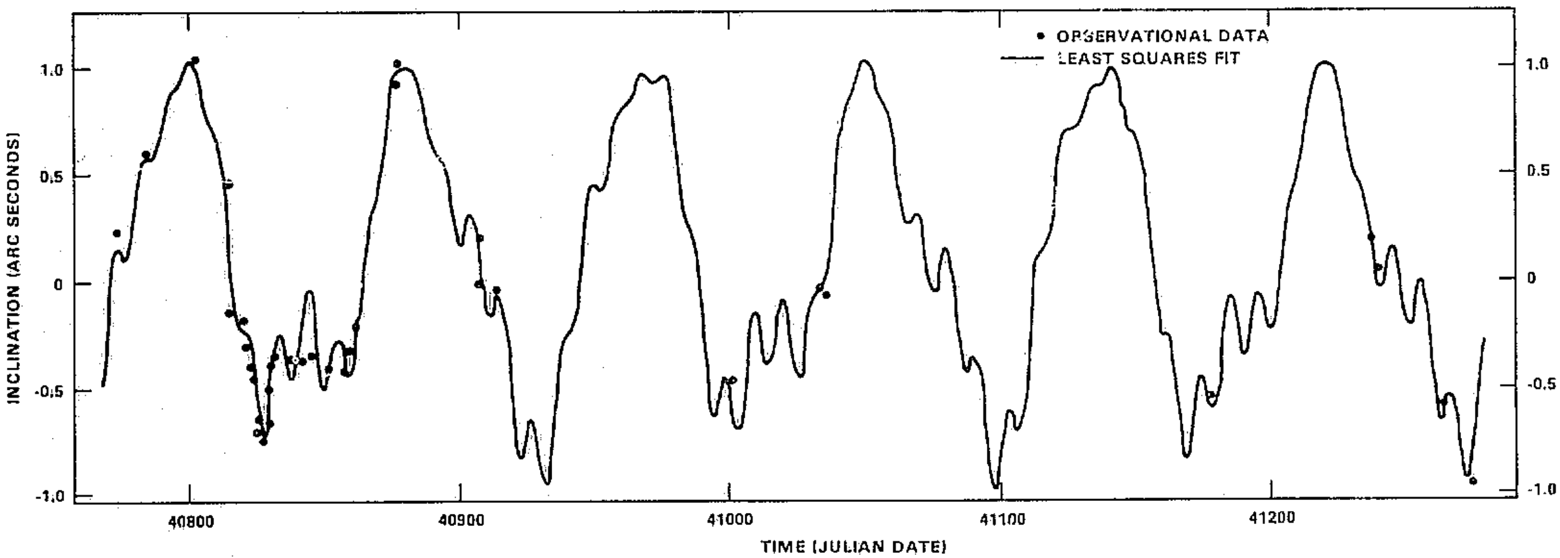

Figure 1. Inclination Data and Regression Curve for BE-C

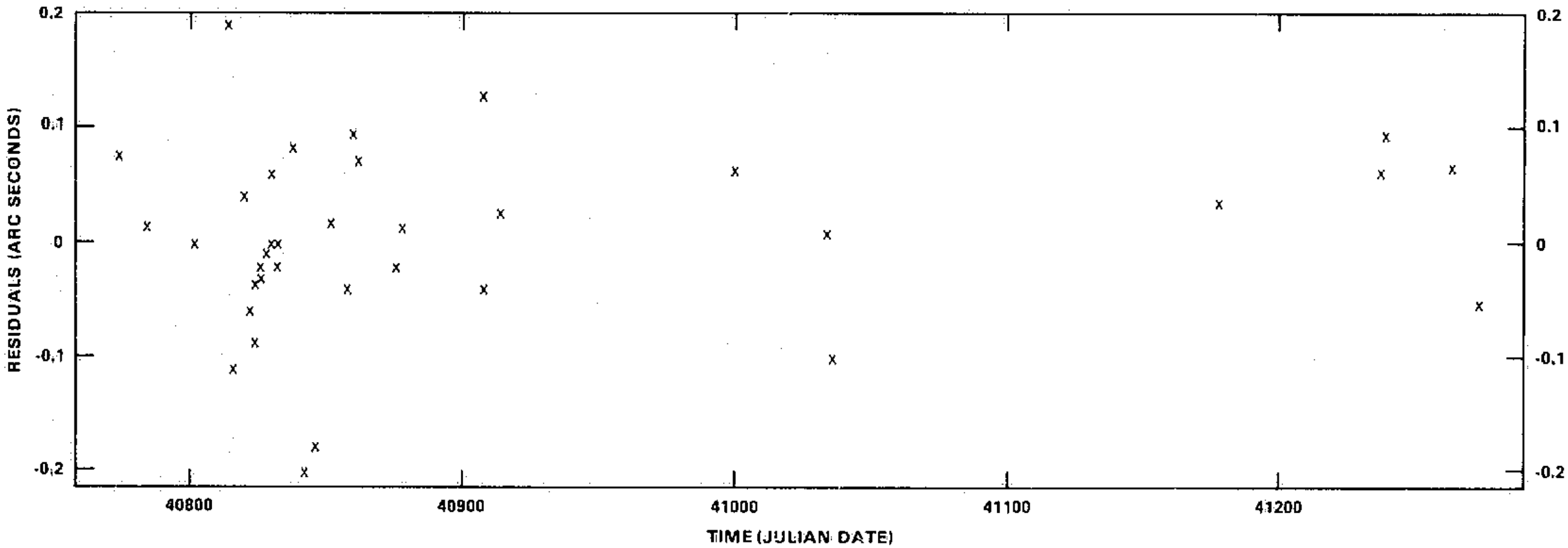

Figure 2. Residuals for Regression Curve Shown in Figure 1.
Standard Error of Estimate: 0.0626

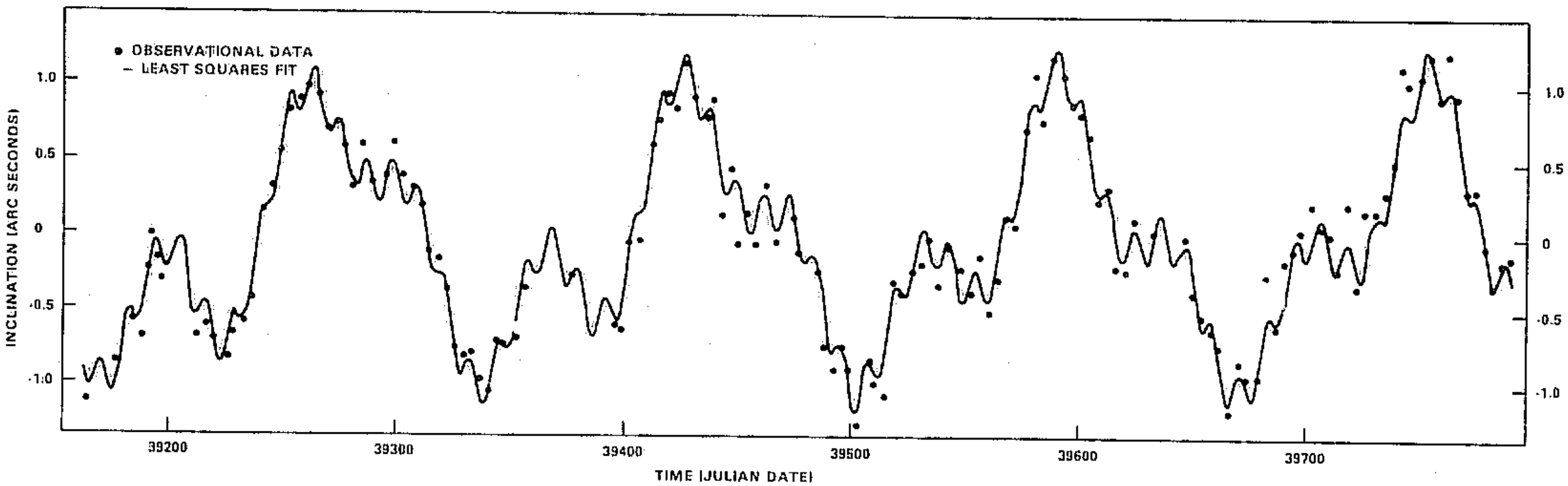

Figure 3. Inclination Data and Regression Curve for GEOS-I

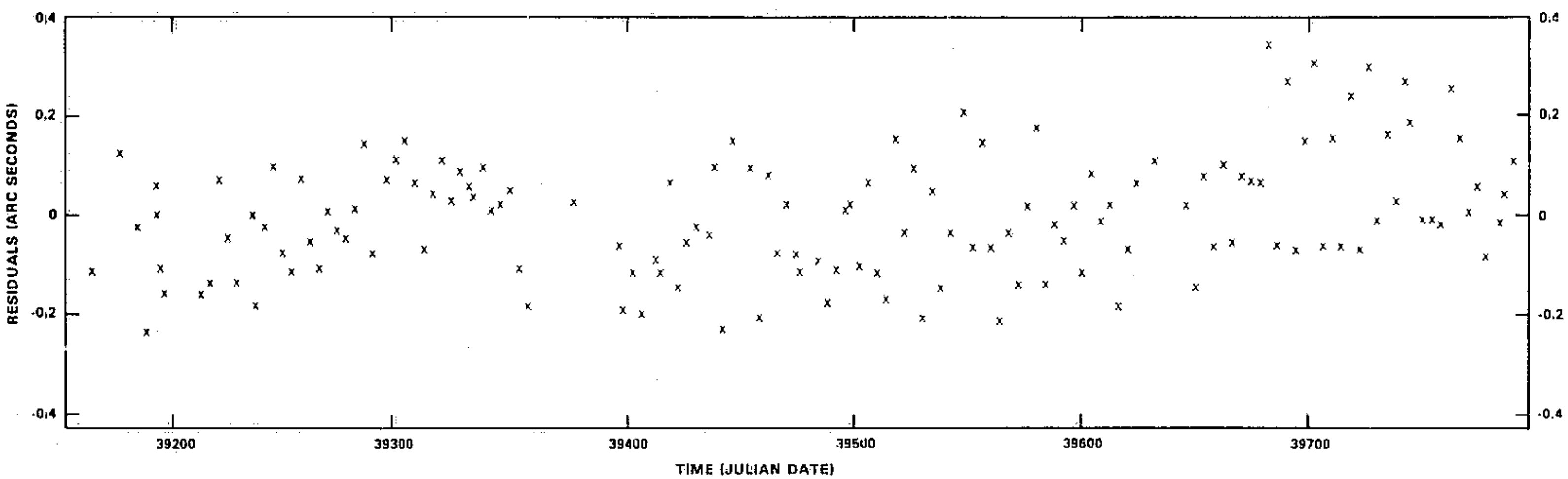

Figure 4. Residuals for Regression Curve Shown in Figure 3.
Standard Error of Estimate: 0.132

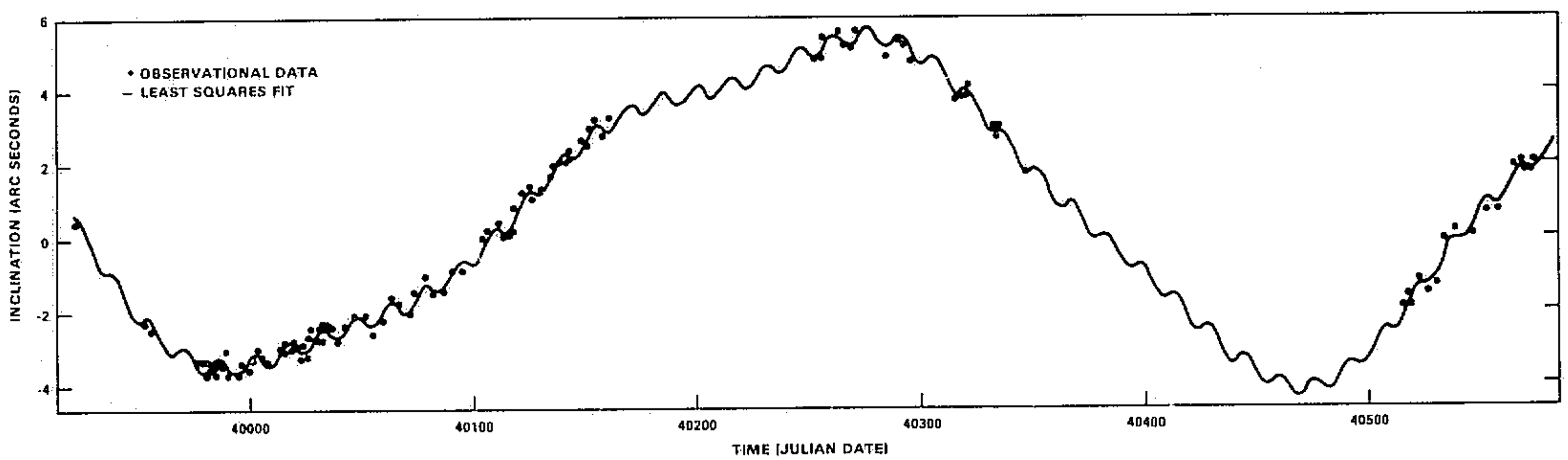

Figure 5. Inclination Data and Regression Curve for GEOS-II

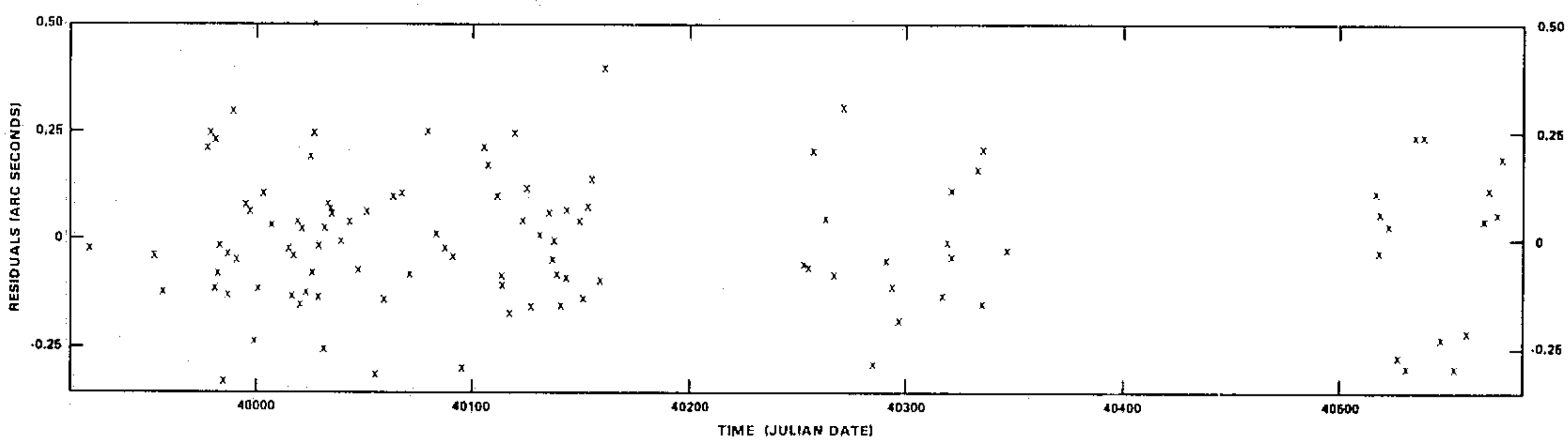

Figure 6. Residuals for Regression Curve Shown in Figure 5.
Standard Error of Estimate: 0.175

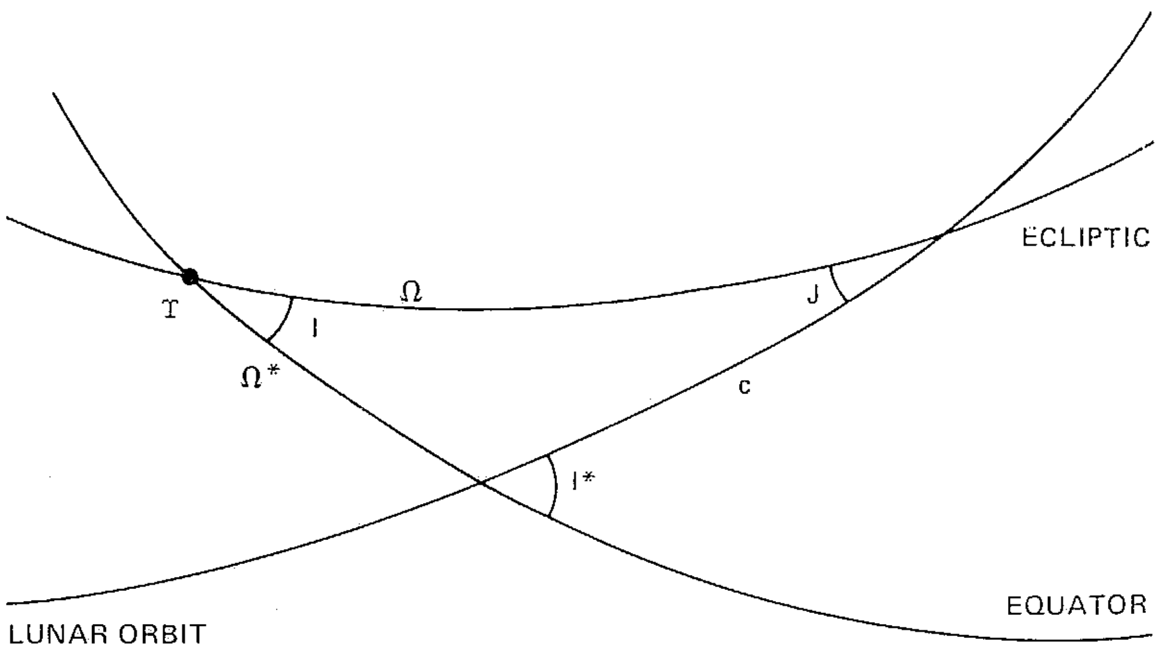

Figure 7. Spherical Triangle Used for Computing the Moon's Position With Respect to the Earth's Equator